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NOTES ON THE DESIGN AND OPERATION OF THE WESTINGHOUSE HORIZONTAL DOUBLE-ACTING GAS ENGINE.*

GENERAL FEATURES.

The Westinghouse, horizontal, four-stroke cycle, double-acting, gas engine may be considered the acme of some ten years development work in various types and sizes of gas engines at Pittsburg. During these ten years 1,054 engines, of all types, have been made or ordered. These aggregate about 140,000 B. HP. and average a little over 130 HP. per unit. While the majority of these engines are running on natural gas yet the largest plants use some form of manufactured gas such as that from blast furnace, coke oven or producer. For the comparatively richer gases, say of 80 to 1,000 B. T. U. per cu. ft., the same relative engine proportions are used, while with the leaner gases cylinder diameters and compression pressures need to be slightly increased to equalize engine ratings for the various gases.

Within the past year material advance has been made in the commercial application of producer gas to all classes of power service and this development has carried the advance of large gas-engine units with it. At the end of March, 1908, there were 122 plants equipped with 271 Westinghouse producer-gas engines, aggregating 68,000 B. HP., with an average of 558 B. HP. per plant, or 251 B. HP. per engine. The producer-gas plants have been for both anthracite and bituminous coal. The most successful producers have been continuous operating ones in which the tar formed is converted into a fixed gas before leaving the producer.

The best proof of the ability of a properly designed, horizontal, double-action gas engine to meet the requirements of modern power plant service lies in the possibility of long continuous runs. In the mills of the Iola Portland Cement Co., at Iola, Kan., gas engines are normally in continuous operation, and the record of eleven months shows 93.2% of actual continuous running for the horizontal engines and 97% for the vertical types. Of the outages, 1.32% of the total elapsed time, in the case of the horizontal engines, and 1.6% for the vertical, were for engine inspection and repair. The rest of the outages were due to plant and mill troubles. Two 3,000-HP. air-compressor engines operated on an average of 93% continuously for four months. Such continuity of operation has been greatly assisted by complete automatic lubrication.

Contrary to a somewhat general apprehension, parallel operation of gas engine-driven alternators has ceased to be a prominent difficulty except for extreme frequencies. Even spring couplings are not used on the horizontal engines except in very special cases. The actual cyclical variation due to impressed crank efforts has been reduced to a fraction of that now considered permissible in steam-engine practice. There is a sufficient reduction of cyclical variation so that the engines could operate on "three legs"—with one side of one cylinder useless.

FIG. 1. WESTINGHOUSE HORIZONTAL DOUBLE-ACTING GAS ENGINE, DIRECT CONNECTED TO ELECTRIC GENERATOR.

With a governor controlling the mixture at the inlet to each cylinder a speed regulation of 2½%, between no-load and full-load, is attainable.

In rating this type of Westinghouse engine the full load has been placed 10% below the maximum load the engine can carry for a considerable period. This is not the absolute load limit, however, as the engine can carry still greater loads for corresponding shorter periods. Moreover, a certain range of fluctuation in the heat value of the gas is provided for in this rating; an engine rated for gas of 125 B. T. U. is capable of carrying full load with gas as low as 100 B. T. U.

Economy of a four-stroke cycle gas engine is largely independent of the size of the unit, so that a unit of 200 or 300 HP. is nearly as efficient in heat consumption as one of 1,000 HP. or over. The heat consumption is close to 10,000 B. T. U. per B. HP.-hr., irrespective largely of the kind of gas used, for the lean gases will stand higher compression up to 200 lbs. per sq. in. for furnace gas.

SPECIAL FEATURES.

In the development of the four-stroke cycle engine the designers of the Westinghouse horizontal type have worked toward maximum simplicity and have evolved a self-contained machine without auxiliary pumping apparatus, if the small air compressing and storage outfit necessary for starting, be excepted.

CYLINDERS.—In the smaller sizes of the horizontal engines the cylinders are symmetrical, one-piece castings with an opening in the jacket walls to avoid shrinkage in casting. The cylinders of large sizes are cast in halves to insure sound castings with the best metal at the center of the cylinders. The two halves are fitted at a ground joint with arrow heads shrunk into the cylinder flanges. The cylinders are supported at the ends and mechanically are simple cylindrical beams supporting only their own dead weight. The weight of pistons and rods is carried by the crossheads.

Quick access to the interior of the cylinders is possible through the inlet valve opening so that it is not necessary to remove a head. As seen from Figs. 1 and 3 all the inlet valves are in a line at the top of the cylinder. The spent gases exhaust downward without entering any pockets, so that heating and contamination of the incoming mixture is avoided. Changes in compression volume to accommodate the design to various qualities of gas can be made without changing the design of cylinders or pistons and without changing the location of valves.

PISTONS.—Pistons are cast in one piece in symmetrical form without internal ribs or corners. Piston-rods are made in two parts to permit removal through front and rear housings and to reduce the building clearance for a through rod. The rods are hollow for cooling water and, although supporting the piston heads, they are not cambered but are designed stiff enough to carry their load without excessive deflection.

SHAFT AND BEARINGS.—All sizes of this type of engine are of side-crank construction, necessitating the alinement of but two bearings. In the smaller engines the shafts are solid forgings, but the larger sizes are bored hollow. Crank, counterweight and crank pin are cast in one piece, with the pin at the bottom of the flask. This design is necessary because of the short stroke and large shaft diameter. For engines up to 1,000 HP., three-part bearings are used, and above that four-part bearings, resting in spherical seats.

VALVE GEAR.—One eccentric operates an inlet and exhaust valve instead of individual cams or eccentrics. The motion is transmitted by pull rods to a rocking cam motion, which gives maximum power at opening with rapidly

*From information furnished by Mr. J. R. Bibbins, Assoc. M. Am. Soc. M. E., Westinghouse Machine Co., East Pittsburg, Pa.

increasing displacement as the valve opens. These eccentrics are carried on a lay shaft, which is driven by spur and bevel gears.

The governing is accomplished for each cylinder directly at each inlet valve, which serves to mix the gas and air and to govern. To this

IGNITION.—Make and break ignition has been adopted to the exclusion of all other systems, after much experimenting, as the most practical for average conditions. Jump spark ignition proved satisfactory on rich gas, but showed erratic results with the high compressions used

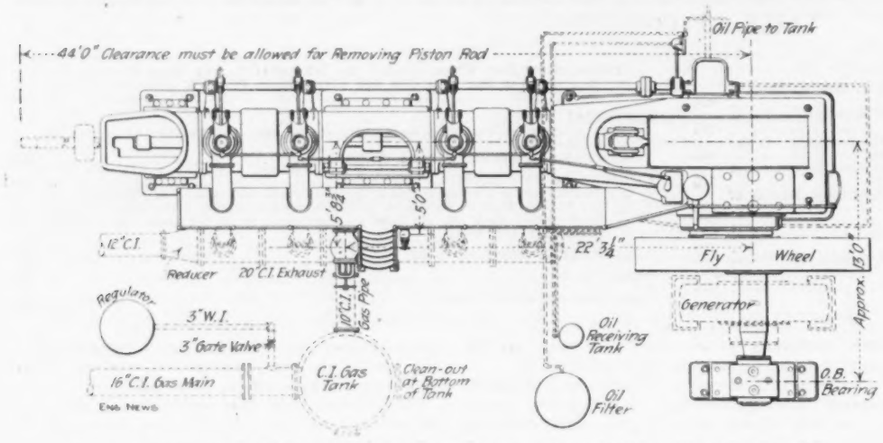


FIG. 2. PLAN OF A WESTINGHOUSE HORIZONTAL GAS ENGINE AND ACCESSORIES.

end the valve has two distinct motions; one due to the eccentric and cam, mentioned before, and the other due to the rotation of a loose, internal, ported sleeve controlled by the regulator. The function of the rotating sleeve is that of a simple throttling governor which increases or diminishes port openings according to the demands of the load. The regulator itself is a purely centrifugal type of European design—the Hartung or Jahns. It is driven from the engine shaft directly and its motion is transmitted to the inlet valves by reach rods, easy distinguishable in Figs. 1, 2 and 3. Motion is not imparted directly to these reach rods but through a pressure, oil-relay system, which relieves the regulator of the work of moving any heavy valve parts.

To provide for the possibility of any disablement of the regulator, a safety stop is attached. This consists of a spring balanced plunger in the fly-wheel rim. At a critical speed the centrifugal force of the plunger overcomes the resistance of the spring and a plug emerges to trip a pawl and open the igniter circuit. In some plants a device has been installed to open the igniter circuit should the water supply in the jackets fail. This latter device operates by the movement of a loaded diaphragm under the pressure of the jacket-water supply.

The exhaust valves are of cast iron or steel, or a combination of both, and are hollow for water cooling.

in blast furnace gas practice. Platinum points are now entirely eliminated and cast iron or a special bronze is employed for the moving contact, working against steel. A light current is furnished by a small motor-generator set at comparatively high voltage. Both sides of the igniter circuit are thoroughly insulated by mica washers, thereby making a double ground necessary to put an igniter out of commission. Vent holes are drilled through the igniter cap to permit the escape of any gases or vapors which would otherwise be condensed inside. In the event of a serious ground, an igniter immediately insulates itself by the blowing of a fuse, one of which is inserted in each independent circuit. The igniters may be removed from one cylinder, while the engine is in operation, by shutting off the gas and blocking open the exhaust valve.

In the smaller engines two igniters are provided for each combustion chamber, and in the larger sizes three are placed at equidistant points. A more rapid and complete combustion results by the use of additional igniters, and there is a gain of nearly 4% in mean effective pressure.

Two distinct types of gears are available for operating the igniters; the one entirely mechanical and the other electromagnetic. The latter is in many ways preferable and has several interesting features. Its action may be studied in connection with Figs. 5 and 6. The peculiar shaped electromagnet closes the circuit outside the cylinder and immediately afterwards trips the igniter so that contact is broken inside the combustion chamber. The operating electromagnets themselves furnish the inductance ordinarily provided by spark coils, and it is evident that the apparatus will indicate trouble at once, whether in the magnet or igniter. This constitutes a tell-tale which, in the mechanical system, must be provided separately in the form of a small panel carrying choke coils fitted with iron sounders which trip in succession as the igniter contacts are made. The contactor for this system provides a ready means for advancing or retarding the moment of ignition by properly rotating the frame to which the contacts are attached. Such a change in ignition point is necessary with gases of varying richness.

The mechanical system of operating the igniters has the common "knock off" cams geared to the lay shaft through adjustable drivers for advancing or retarding ignition as needed.

LUBRICATION.—The entire lubrication of the horizontal type of engine is automatic. Force-feed lubricators are employed for the cylinders and the oil discharge is timed so as to reach the piston at the close of the power stroke when covering the oil ports. During two strokes then, at low temperatures, the oil has a chance to get evenly distributed over the entire surface of the cylinder. Good lubrication is secured with a small supply of oil; in several 500-HP. plants, the consumption of cylinder oil is down to three to five gallons per week of 10-hr. days.

Engine oil is served by a gravity system, including pump, filter and elevated reservoir with individual sight-feeds, all controlled by a single valve, so that individual adjustments, once set, need not be changed. Here the oil waste due to evaporation, leakage and renewal is reduced to a minimum.

COOLING.—To reduce the quantity of cooling water required a series circulating system has been employed to a certain extent. As pistons and cylinder heads have about the same exposed surface, these parts are connected in series. Water enters the piston through telescopic connections at the center crosshead, discharging front and rear into chambers cored out of the housings. The velocity of water through valves, rods and pistons is placed high enough to prevent the deposit of sediment. The jacket spaces about the cylinders are ample to allow cleaning out sediment which may accumulate there. Each cylinder and each exhaust valve have individual circuits and separate cooling-water discharges, so that it is possible to follow closely the condition of each of these parts. A water pressure of 25 lbs. per sq. in. is sufficient for supplying all cool-

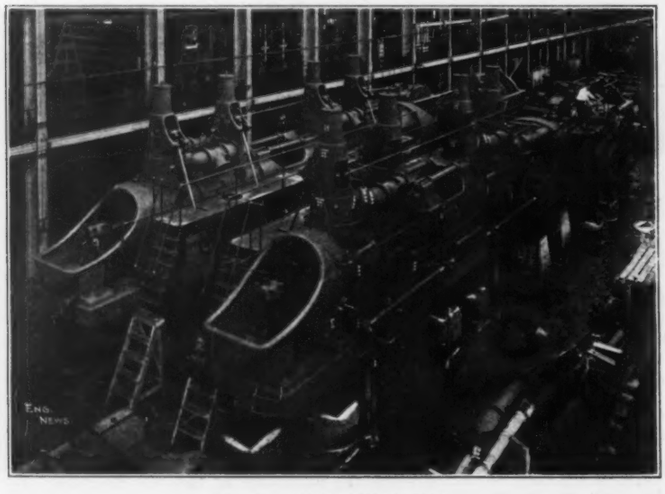


FIG. 3. GAS-ENGINE END.

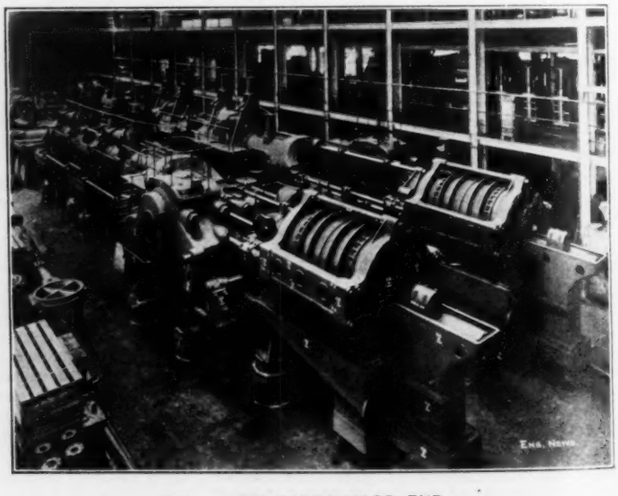


FIG. 4. AIR-COMPRESSOR END.

FIGS. 3 AND 4. A FOUR-STROKE CYCLE, DOUBLE, HORIZONTAL, GAS DRIVEN, BLOWING ENGINE; DURING ERECTION IN THE SHOPS OF THE WESTINGHOUSE MACHINE CO., EAST PITTSBURG, PA.

ing circuits, and in some cases where exceptionally pure water is available a pressure of 12 or 15 lbs. per sq. in. may be sufficient.

STARTING. — The horizontal engines are started by compressed air automatically admitted by poppet valves and cams on the lay shaft. The

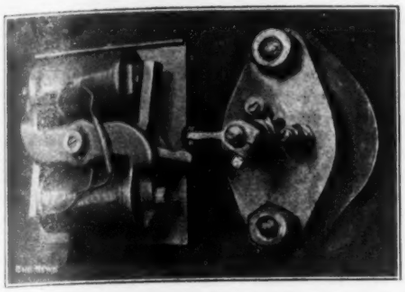


Fig. 5. Igniter and Electromagnetic Operating Gear; Westinghouse Horizontal Gas Engine.

engine starts itself when the compressed air and gas valves are opened and the ignition circuits are closed. As each cylinder picks up its ignition the compressed-air supply is automatically cut off by a check valve held to its seat by the combustion pressure. When the air is shut off, the admission valves drop out of engagement by their own weight.

GAS - PRESSURE REGULATOR.—As the pressure of any supply is subject to considerable variations, it is necessary to provide an automatic regulator in the supply line to insure maintaining the proper mixture at the inlet valve. The main pressure regulator consists simply of a butterfly valve in the supply line and controlled by a small gasometer connecting with the gas main. In some cases it is also desirable to provide a cast iron or steel tank in the basement of the engine room to dampen the pressure fluctuations resulting from the intermittent demand of the engine cylinders.

AS A BLOWING ENGINE.—The gas engine end of the power unit is exactly the same whether an electric generator or a blowing tub is driven. With the Slick design shown in Fig. 4 the engine housings may be placed closer together. These blowing units are built to furnish air at 10 lbs. per sq. in. normal or 25 lbs. maximum pressure for short periods. On account of such low cylinder pressures no water jackets are provided.

The blowing-tub pistons are driven by side rods connecting the engine and tub crossheads. A unique feature of the Slick design is that the cylinder heads only are attached to the housing while the cylinder body is reciprocated. To this end connecting rods pass from trunnions cast on the cylinder bodies to cranks carried on a rocking shaft driven by eccentrics from the engine shaft. The ends of the moving cylinder bodies have ports, around the circumference, which are covered or uncovered by the movement of each end into and out of its cylinder head. These ports admit air to the cylinders during the suction stroke, the discharge on the compression stroke being through valves in the cylinder head. The joints between the cylinder heads and body are made tight by a snap ring in a groove in each cylinder head. In this design, with the inlet valves mechanically operated, the pressure drop in getting air into the tub against spring valves is removed and the clearance losses are reduced.

Here as in the gas engine end, the weight of the blowing piston and rods, is carried by the crossheads, the piston having a clearance of about an eighth of an inch around its entire periphery. Four slippers sliding on machined ways support the weight of each cylinder body, preventing the wear on the heads that would result if they carried the weight of the body.

SEWAGE DISPOSAL INVESTIGATIONS BY THE UNIVERSITY OF WISCONSIN.

By GEORGE JACOB DAVIS, Jr.,* Assoc. M. Am. Soc. C. E.

There are at present in operation in the State of Wisconsin a number of sewage disposal plants, most of them employing septic tanks and some using filter beds of various materials. A few of these plants are at public institutions, such as the State Hospital for the Insane and the Milwaukee County Poor Farm; others treat the sewage of towns and cities varying in size up to 30,000 population; and quite a considerable number of others treat the wastes from dairy stations.

The climatic and other conditions of Wisconsin, being somewhat different from those of any other locality where sewage disposal has been studied, render the conclusions of such studies of doubtful utility in that State, and as the subject is gaining in importance it was decided to make a study of the existing plants of the State under actual working conditions. The study of the municipal and institutional plants is under the direction of the writer, and is provided for by the Department

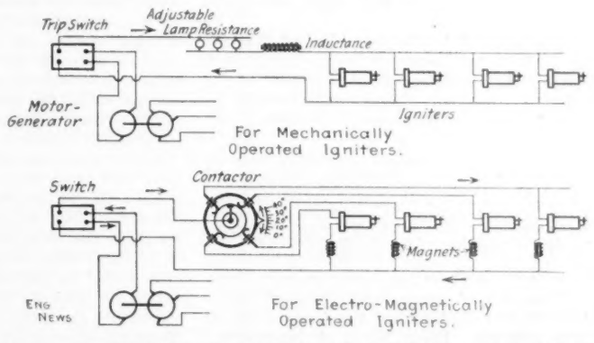


FIG. 6. IGNITION CIRCUIT DIAGRAMS OF HORIZONTAL GAS ENGINES; WESTINGHOUSE MACHINE CO., EAST PITTSBURG, PA.

of Hydraulic and Sanitary Engineering of the University of Wisconsin, while the study of the dairy disposal plants is under the direction of Prof. E. H. Farrington and is provided for by the Dairy School of the University. The coöperation of these two departments with the State Hygienic Laboratory has made it possible to prosecute the work in an efficient manner. The analytical work is done by Mr. J. T. Bowles, Chemist of the State Hygienic Laboratory.

The investigation was begun last summer by studying the operation of the University Dairy School disposal plant, which was giving very poor service. The plant at the State Hospital for the Insane at Mendota, about five miles from Madison, and the Madison municipal plant, were next taken up. Several other plants will be studied this spring, as soon as the operation of the filter bed commences. It has been the custom in all the plants to dispense with the operation of the filters during the winter. It is known that most of the plants are giving very poor service, and this fact is largely due to lack of interest, and in many cases to ignorance on the part of those in charge. In some cases the plants are deficient in size or in design, but usually will give good results if properly managed. Commendable interest and willingness to coöperate in the work has been shown by the authorities in charge of some of the plants. It is believed that by studying the conditions at the various plants and interesting the local authorities and recommending to them the proper steps to be taken to secure an efficiently working plant the university will be performing an immediate and important service to the State.

The scope of the work as planned involves:

(1) The determination of the efficiency of the various sewage disposal plants of the State under the present conditions and methods of operation.

(2) The determination of whether the causes of inefficiency, in those plants that are doing unsatisfactory work, lie in faults of design, construction, or of operation.

(3) Securing the interest of local officials in making such changes in operation or construction as will improve the efficiency of the plants.

(4) The acquiring and publishing of accurate data and information, concerning the essential elements in the design and the cost of construction and operation of the various types of plants, which will be of assistance to communities intending to construct disposal plants.

Visits are made to the various plants under investigation, during which an examination of the condition and operation of the plant is made and arrangements perfected for procuring and shipping the samples of sewage and effluent to the laboratory at Madison. All of the plants studied so far are within a comparatively short distance of the laboratory, so that no preservatives have been used in the samples.

A sanitary survey of the water supplies of the State has been planned and some work has been done along this line by Mr. Bowles.

*Assistant Professor of Hydraulic Engineering, University of Wisconsin, Madison, Wis.

FORESTRY IN KOREA is to be taken up by the Government under new forest laws, said to have been enacted under a cooperative agreement drawn up by Japan and Korea. It is also reported that a school for training Korean foresters has been established.

A NATIONAL ARCHITECTURAL EXPOSITION will be held Sept. 14-19, at Madison Square Garden, New York City. Its scope will include all departments of Architecture, Engineering, Painting, Sculpture, the Trades, Manufacturing and Craftsmanship pertaining to the construction, equipment and decoration of buildings as well as landscape and garden effects. The enterprise is being promoted by Mr. Alfred Chasseaud, 1 Madison Ave., New York City.

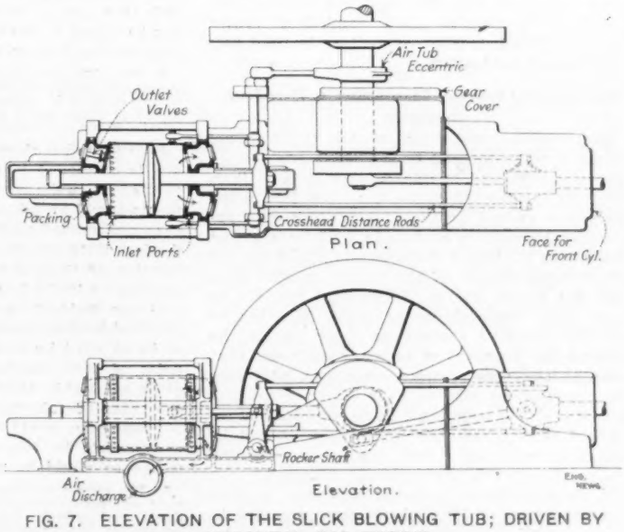


FIG. 7. ELEVATION OF THE SLICK BLOWING TUB; DRIVEN BY HORIZONTAL GAS ENGINE.

WIRELESS CONTROL of a storage-battery motor-truck is in an experimental stage at the Omaha shop yards of the Union Pacific R. R. A wireless telegraph coherer, in connection with a small antenna or form of wire wing, has been attached to the truck for opening and closing the motor circuits. The waves are sent out from a pole at the power-house and are used only for the control.

THE RELATION OF WATER CONSERVATION TO FLOOD PREVENTION AND NAVIGATION IN THE OHIO RIVER.*

By M. O. LEIGHTON,† Assoc. M. Am. Soc. C. E.

This report will be confined to a statement of possibilities. There will be no attempt to prescribe methods for treatment of each local modifying condition that will be encountered in the prosecution of the plan here proposed. Such features are merely collateral, and their proper disposition is a matter of ordinary engineering.

It is not expected that the facts here set forth will refute all the objections made in past years to the conservation scheme. Such, indeed, is not the object. The paper will have served its purpose if it demonstrates that the plans proposed have so many features of promise that it would be a grave mistake to recommend the permanent adoption of a governmental policy that did not recognize the possibilities and provide for a further and more minute investigation of them.

Briefly stated, the contentions are as follows:

1. That the logical way to control a river is to control the sources of its water supply.

2. That in nearly all of the rivers of the United States such control can readily be effected by the construction of storage reservoirs.

3. That the way to prevent floods is to use these reservoirs to catch and temporarily hold the flood waters, so that they will not descend upon the lower valleys in so large unit volume.

4. That in the majority of cases the improper and illogical way to attempt the control of floods is to endeavor to confine the rivers between high and expensive levees.

5. That except along those portions of river channels that are too steep for open navigation, the proper way to maintain navigable depth at the low-water season is to provide, if possible, for the intelligent release of stored water.

6. That canalization of rivers should be the resort only along those portions of the channel too steep for open navigation or in the tributary basins of which sufficient flood water cannot be stored to maintain navigable depth at low water; further, that when such results may be derived from storage reservoirs, canalization is disproportionately expensive in maintenance and the money so expended might be used for more useful purposes in the uplands.

7. That while the first cost of the proposed conservation system will be large, the burden will be widely distributed over a series of years necessary to complete the construction.

8. That the ultimate cost will appear nominal when compared with the enormous benefits conferred, these benefits being applied to water power and to irrigation, as well as to flood prevention and navigation.

The History of Reservoir Construction for River Flow Regulation.

The general proposition in this paper is not new. It was proposed by a British engineer in the year 1800, and in this country by Mr. Chas. Ellet, Jr., nearly 60 years ago. An interesting discussion ensued at that time, which was apparently brought to a close in 1867 by a report of the late W. Milnor Roberts. So effectively did Mr. Roberts dispose of the matter at that time that the policy of the Government appears to have been well-nigh crystallized. Whether or not Mr. Roberts' contentions were correct, he enlisted the approval of so many engineers that even at the present time when one advocates the conservation scheme he is almost certain to be met with the question, "Have you read the report of Milnor Roberts?" Therefore, it will be profitable to review briefly the points of objection made by this distinguished engineer.

In the first place, it should be borne in mind that the report of Mr. Roberts was presented in the year 1867, when the country tributary to the Ohio River was, so far as special topography and reservoir facilities are concerned, practically an unknown region. At the outset of his presentation, Mr. Roberts made a very sensible observation that applies with equal force today, viz.:

> The question is not merely one of dollars and cents that may be involved in the adoption and completion of a particular plan; it is of the first consequence that that plan shall be one with which the sober good sense of the country will rest satisfied and which in the end will be productive of the greatest benefit.

In considering the objections of Mr. Roberts the author will use an abstract of the same made by Major William E. Merrill, Corps of Engineers, the successor, friend and supporter of Mr. Roberts. This abstract appears in the report of the Chief of Engineers for 1873, Vol. 1, pp. 500 to 501, inclusive.

1. Six such sites cannot be found on the head waters of the Ohio and an increased number of smaller reservoirs would be needed.

Mr. Roberts' criticism here is a reply to Mr. Elwood Morris, an engineer, who in support of the ideas of Mr. Ellet, calculated the effect of such storage on the Ohio River by assuming hypothetically the existence of six reservoir sites, each capable of conserving the drainage from 600 square miles. Indeed, a large part of Mr. Roberts' report is devoted to a demonstration of the fact that six such sites are not to be found in the Ohio basin. Mr. Morris, himself, merely assumed the possibility of sites for these reservoirs for purposes of calculation.

2. These dams would destroy all raft or flat boat commerce above them. Arrangements that might be made to provide a passage by chute would not answer when the reservoir was not full, which might often happen.

The conditions of traffic that allowed this objection to be taken seriously have now passed. At present, the conditions of transportation are such that we are not giving much thought to raft and flat boat commerce on the highland tributaries of any stream.

3. There would be great danger of breakage from unforeseen leaks or accidents. Reservoirs constructed on dry ground have sometimes broken and the danger is much greater in a running stream. Should one such dam break it would probably carry all others lower on the same stream and pour a frightful wave of destruction on the valley below. The possible loss of life and property that might ensue is beyond all estimate.

We know more about reservoirs than in those days. There are, of course, possibilities of breakage, but this has not inhibited the development of reservoir systems. Every piece of construction made by man is liable to failure. Life itself is hazardous. If the objections here recorded were used consistently with reference to all modern economic development, mankind would be crouching on the ground in the open country, shaken by apprehension. Every feature of our development makes it necessary to assume hazards, and modern engineering has rendered the reservoir so safe that, as an agent of violent death, it cannot be placed in the same class with the ordinary morning stroll down the streets of a great city.

4. The damages on account of farms overflowed, towns, oil wells and manufacturing establishments submerged, railroads compelled to rebuild their lines on higher levels so as to get above the dams, and similar injuries would add very greatly to the cost of the system.

It is true that there would be submergence, yet one is compelled to reflect whether more farms, towns, oil wells and manufacturing establishments would be submerged beneath the reservoirs than are annually submerged by the unrestrained floods. With reference to railroad lines, the relocation of them does not appear to us so formidable as it did in those days. Indeed, it is an ordinary incident in railway maintenance. The whole objection assumes that enormous losses are to be entailed by such submergence, whereas, in point of fact, reservoirs are constructed in regions not highly developed in this way and where the cases of submergence are merely incidental. No sane man would advocate the construction of a reservoir in places where the cost of submergence would be excessive.

5. The utmost care would be necessary in the management of these reservoirs to prevent injury by sudden floods, and terrible disasters might ensue from carelessness or bad judgment.

This indictment is accepted. We are all subject to the good judgment and management of our friends and associates in the controlling conditions in our everyday life, and it is to be presumed that each man will do his duty. Whether we travel or remain at home, we are constantly subject to the operation of utilities that cannot be made fool-proof, and there is no reason for assuming that the management of reservoirs is extra-hazardous. On the contrary, it is a comparatively simple matter.

6. The proper use of the reservoirs would be very difficult in order to keep up the exact depth needed for navigation, as any mistakes in regulating the supply would seriously embarrass navigation. Special telegraph lines would have to be constructed to all reservoirs and widely extended observations on the rainfall and the conditions of all tributaries would be needed in order not to waste nor to unduly economize the supply.

We are ready to meet all of Mr. Roberts' requirements in this matter. We have extended observations on the rainfall and the conditions of all tributaries and we could do even better than he suggests in the way of communication, for we could supply telephones. It is readily recognized that this objection is antiquated and not worth considering in the light of modern improvements.

7. The cost of the reservoir system would be very great and could only be estimated by careful examinations at each site selected. Estimates based on a specially favorable site could not be depended on.

All this is accepted as one of the trivial incidents of reservoir construction. Of the cost we shall speak later on.

8. The whole thing is an enormously costly experiment and would require the continuation of the present system of improvement by riprap dams and dikes in order to utilize the water delivered.

It is true that the system would be costly, yet, as will be shown later on, the relative cost compared with the benefits derived would be small. It is a well known precept of modern business life that values are not determined by cost and nothing may be considered costly that returns a reasonable income on the investment. Some things would be costly if purchased for a farthing. With reference to the scheme being an experiment: that which may truly have been considered an experiment in the day of Mr. Roberts may now be a well-attested reality. The scheme is not an experiment, as will be shown later on. One of the purposes of this paper is to show that Mr. Roberts was wrong in his assumption that *complete channel improvement* would still be necessary if reservoirs were constructed. Indeed, the reservoir is urged as a substitute for such works under certain conditions.

While the objections above cited may have been important at the time they were enunciated, it is clear that they are of little consequence at the present time. The whole matter is brought down to a question of fact, namely, is there available on the highland tributaries of the Ohio sufficient water supply and storage capacity to prevent floods and to maintain deep water navigation during seasons of low water. Mr. Ellet did not have the necessary information at his disposal and therefore could not prove his contentions. Mr. Roberts confessed that he did not have it, but endeavored and, in fact, succeeded in discrediting the idea without it. We are now in possession of it for certain areas as a result of the investigations of the United States Geological Survey and the United States Weather Bureau, and can readily establish certain crucial points that were left in doubt in the earlier discussion.

It will be appreciated on examination of this paper that the region considered does not cover the entire basin. Therefore, this presentation cannot do entire justice to the situation. Whatever results may appear to be claimed as arising from the construction of these reservoirs with reference to the effects of floods and the maintenance of low-water navigation on the Ohio, they do not represent the total possibilities of the region for, were surveys available on all the basin, it is manifest that far greater storage facilities would be shown to be available. Therefore, the maximum effect of conservation would be much greater than shown in the following pages.

It will be helpful now to consider an objection that is frequently made to the use of storage reservoirs for flood prevention purposes, viz.: that there is no way of predicting when floods may come and it would be certain that a flood would descend on the reservoirs when they were filled to overflowing with the runoff from a previous flood. Now, the records of floods during

*A paper prepared as an appendix to the Preliminary Report of the Inland Waterways Commission. See Engineering News, March 5, 1908.

†Chief Hydrographer, United States Geological Survey, Washington, D. C.

the last twenty or thirty years on the Ohio indicate that, while they may not be predicted within a few days, they do occur during certain seasons of the year, and therefore the problem is narrowed down to that extent.

But, supposing this were not so, the effect of the reservoirs would not be diminished. It will be noted in subsequent pages that the extent of drainage area that can be conserved by various reservoirs has been determined. The reservoirs will hold the entire year's runoff from a stated area, or, in other words, if the gates of the reservoirs were allowed to remain closed for an entire year, the reservoirs would retain all the water flowing from that territory for the entire period.

Supposing now, that two floods should descend into the Ohio River, as they did in January and March, 1907. The second flood could not descend on full reservoirs because the capacity of the reservoirs is sufficient to hold them both. We have, for example, on the Monongahela storage facilities of capacity sufficient to conserve the runoff of 38% of the drainage area. Therefore, according to the adjusted capacities stated in the following pages, this per cent. of the drainage area could be entirely cut off from the Ohio valley for the period of one year.

Of course, this estimate is based on the records of mean flow, as shown by observations extending over a series of years. There is considerable variation from one year to another, so that if the reservoirs actually remain closed, there are years in which the accumulation of water would more than fill them and still other years in which the accumulation of water would not suffice to fill them. But the point is that this great capacity furnishes a wide margin on which to work. The two floods of the spring of 1907, for example, would not fill these reservoirs, but, assuming that they remain closed for the entire year, it is possible that the entire year's runoff would more than fill them. But with this wide margin of time, covering indeed a low-water season, when the water would be needed in the Ohio, there is ample time to draw off the water and prepare the reservoirs for subsequent floods.

Therefore, the criticism that floods might descend upon reservoirs already filled is based on the hypothesis that the reservoirs are small and their capacity is not commensurate with the size of the basins, whereas, in point of fact, they are sufficiently large for flood prevention. The whole matter therefore comes down to intelligent manipulation, with margins of safety so wide that only the most flagrant stupidity could result in any misfortunate circumstance.

A further question now to be discussed is, how are we going to manipulate the reservoirs above which there is a large drainage area and the capacity of which is only sufficient to hold a portion of the flood descending from that area? A glance at the tables in subsequent pages will show that there are many such.

This is a mere matter of intelligent manipulation. We will assume, for example, that there is above a certain reservoir a drainage area of 100 square miles, while the reservoir itself has a capacity sufficient to conserve the runoff from only 50 square miles. This does not make it necessary that the runoff from the 100 square miles shall come down and overwhelm the 50-square mile reservoir. The fact should be kept in mind that this reservoir is to conserve the drainage from only 50 square miles and therefore as fast as the flow comes down into the reservoir one-half of it should be released through the gates. The release of one-half of the water may readily be accomplished by adjusting the size of the openings in the reservoir gates.

The same effect could be readily produced if the drainage area above the reservoir were 1,000 square miles in extent and the reservoir capable of conserving only 10 square miles. The flow into the reservoir from the upper channel can readily be rated and it can be known at any time from observation of the gage how much water is coming into the reservoir. Knowing the proportion of the drainage area which the reservoir will conserve, it is merely necessary to raise or lower the gates so that the portion which it is not intended to conserve may be discharged from the reservoir as fast as it comes in.

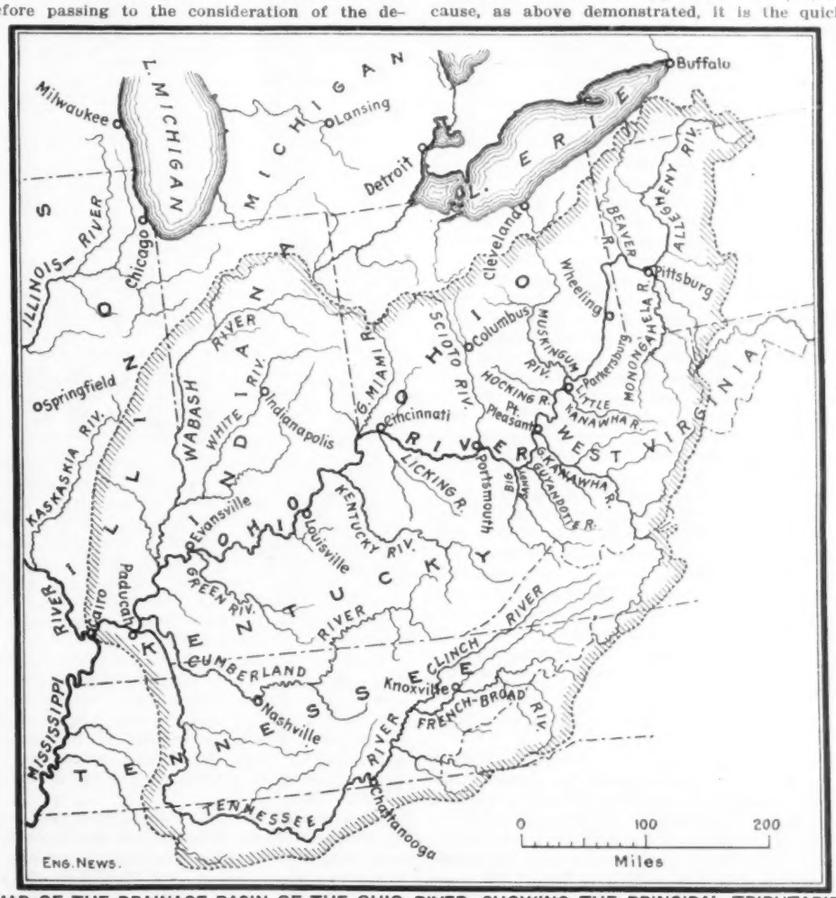
The computation of the proper amount is a simple engineering calculation and would not require expert manipulation on the ground. Simple directions based on these calculations could be given to any intelligent man so that he could manipulate the gates of the reservoir according to the amount of water coming in, in precisely the same way as the unprofessional attendant of reservoirs on city water-works is instructed by a few simple rules to manipulate the gates according to the consumption. These considerations, it is believed, will dispose of the oft-repeated assertion that a second flood might descend after a first and upon full reservoirs.

Another preliminary statement should be made before passing to the consideration of the detailed facts concerning the reservoir system. It will be admitted that the reason why a river will overflow its banks is because so great an amount of water is turned into the channel within a short space of time. If the total annual flow of a river were uniform there would be no floods. It is the great influx of water derived from heavy rains and quickly melting snow that overtaxes the channel.

The question now arises, what are the factors that control the speed with which runoff water is discharged into river channels. The answer is plain, namely, the slope of the tributary country and the condition of the land surfaces. It is clear that the water of precipitation will run off the side of a mountain more quickly than off the surface of a plain. Therefore, it must also be clear that the most destructive part of a flood originates in the steeper part of the drainage area, and consequently, if the speed of this part of the runoff could be inhibited, the severity of floods would be greatly reduced.

Bearing this in mind, it will now be profitable to consider what portions of the various drainage areas of Ohio River tributaries it is proposed to conserve in the present instance. A glance at the locations will show that almost invariably it is these quick-spilling upland areas above referred to, but it should be noted that a reservoir system does not merely inhibit the runoff from these steep areas but actually holds and conserves it. It is the lower, flatter portions of drainage areas that remain unobstructed. The situation is ideal because these lower portions are the least troublesome.

The purport of the above suggestions is as follows: It has been stated in a previous paragraph that the reservoir facilities on the Monongahela basin will, if developed, absolutely conserve the runoff from 38% of the drainage area. Other things being equal, it might be stated that the reduction in flood height would be, broadly speaking, a like proportion. Actually, however, the reduction will be far greater than this, because, as above demonstrated, it is the quick-spilling portion that will have been conserved and the more moderate portion that will remain unobstructed. Therefore, in connection with all statements hereinafter made concerning the reduction of flood height by reservoirs it should be borne in mind that the proportion stated is by no means as great as that which will occur in actual practice.



MAP OF THE DRAINAGE BASIN OF THE OHIO RIVER, SHOWING THE PRINCIPAL TRIBUTARIES.
(Dotted Line Shows Boundary of Ohio Drainage Basin.)

Reservoir Possibilities in the Ohio Basin.

Ohio River is formed by the junction of the Allegheny and Monongahela rivers at Pittsburg, Pa. On the Allegheny basin the lack of suitable surveys prevents a full estimate of reservoir possibilities, and those here presented do not cover the entire basin and should not be so interpreted. The Monongahela basin, on the other hand, has been thoroughly surveyed and the amounts stated in the following paragraphs probably represent maximum conservation. In other words, on these two as well as on the remainder of the tributaries, all the available information is given, and deductions are here made on that basis.

We will now discuss briefly the characteristics of the various highland tributaries of the Ohio, their water resources and their availability for storage reservoir installation.

RESERVOIRS ON THE ALLEGHENY RIVER.

The Allegheny River basin above Pittsburg is 11,400 square miles in extent. The greater part of the area is steep and quick-spilling and the deforestation has been quite extensive. The river is subject to wide range of stage and floods are frequent and severe. Except on the lower 25 miles of the river, the principal traffic consists in the down-stream transportation of timber and lumber products. The present project for improvement of the river contemplates the removal of boulders and snag obstructions and the construction of low dams and dikes to close secondary channels and concentrate the low-water flow on shoals. The amount expended under this project to the close of the year ending June 30, 1906, was $200,750, fully one-half of which was applied to maintenance.

The work done has not increased the depth of water, generally speaking, except where dikes or dams have been built, but the removal of the obstructions has made it possible to utilize the entire flow of the stream so that now navigators may operate safely on from 1 to 2 ft. lower stages than formerly. The annual tonnage of the river above slack-water improvements which are now in course of construction is about 400,000, extending over 230 miles from Tarentum, Pa., to Olean, N. Y.

As above stated, a complete survey of the river basin is not available; therefore, no complete estimate can be made of the total possibilities of preventing floods and maintaining navigable stages during low water. The storage capacity that can now be computed is sufficient to entirely conserve the runoff from an area of 1,774 square miles, or 15.6% of the total drainage area. The locations of these storage reservoirs, together with facts concerning them, are set forth in Table I.

The highest runoff from the Allegheny basin, of which there is authentic record, occurred during the flood that began March 22, 1905, when the highest discharge was 272,000 second feet. The total flowing past Pittsburg from both the Allegheny and the Monongahela was 317,000 second feet, showing that, in this region at least, the Allegheny was the principal cause of the flood in the Ohio. This is not usually the case, however, the Monongahela being more often the principal offender.

RESERVOIRS ON THE MONONGAHELA RIVER.

The drainage area of the Monongahela River is 7,400 square miles in extent. Excellent topographic surveys covering the entire basin make it possible to determine with a fair degree of completion the storage facilities afforded by the basin. The character of the drainage area is somewhat similar to that of the Allegheny. The greatest contributor to the flood of March, 1907, was the Monongahela, and the relation of this basin to the Ohio will be discussed in subsequent pages.

The Monongahela is canalized from its mouth to Fairmont, W. Va., the slack-water system comprising 15 dams and 19 locks, the total cost of which to June 30, 1905, was $6,023,605. For the maintenance of these locks up to the same date the United States had paid $1,694,380. A slack-water system is now proposed for the Youghiogheny, consisting of three locks and dams, at an estimated cost of $600,000.

Proper manipulation of the reservoirs that are shown to be available in the Monongahela basin would afford an increased stage above that of low-water at three sections, namely, Morgantown Bridge, Brownsville and McKeesport, as shown in the following tables:

SECTION BELOW MORGANTOWN BRIDGE.

Increase of stage, ft...	1.0	2.0	3.0	4.0	5.0	6.0
Flow required, cu. ft...	545	1,290	2,300	3,600	5,030	6,760
Reservoirs:	(—Duration of Stage (Days).—)					
Full	1,650	700	392	250	170	133
¾ full	1,240	525	293	188	134	100
½ full	825	350	196	125	90	66

SECTION AT BROWNSVILLE, PA.

Increase of stage, ft...	1.0	2.0	3.0	4.0	5.0	6.0
Flow required, cu. ft...	730	1,730	3,070	4,670	6,570	8,730
Reservoirs:	(—Duration of Stage (Days).—)					
Full	1,740	730	410	270	193	139
¾ full	1,300	550	310	203	145	104
½ full	870	365	205	135	96	70

SECTION BELOW McKEESPORT, PA.

Increase of stage, ft...	1.0	2.0	3.0	4.0	5.0	6.0
Flow required, cu. ft...	1,080	2,470	3,940	5,840	8,000	10,340
Reservoirs:	(—Duration of Stage (Days).—)					
Full	1,500	650	410	280	200	156
¾ full	1,120	490	310	210	150	117
½ full	750	325	205	140	100	78

The above tables show that intelligent manipulation of available storage on the Monongahela would provide ample depth for navigation of the river during low-water seasons. It is possible that the money expended for canalization might have been spent to a better purpose in the hills. Now that the dams are erected, the proper course is to erect the reservoirs and produce profitable power on these dams, so that the system will be self-supporting.

The available storage in the Monongahela basin will absolutely conserve 2,800 square miles, or about 38% of the entire basin, the result of which would be to diminish the height of the floods along the lower reaches of the Monongahela by at least 50%. Facts concerning the available storage facilities in the basin are set forth in Table II.

If the above system of storage reservoirs were installed and power developed on the dams that have been erected on the Monongahela for canalization at an expense of over $6,000,000, the income from water-power rental, at an average of $20 per horsepower year, would be $887,000, or an equivalent of a 3% income on an investment of $29,500,000. On the Youghiogheny alone, where it is proposed to install a slack-water system comprising three locks and dams, at an expense of $600,000, proper development of storage will insure the production of a minimum of 4,100 HP., the value of which, reckoned on the exceedingly low price of $20 per horsepower year, would produce a total income of $82,000, which represents an interest of 3% on $2,700,000. This region is a great commercial and manufacturing center and power is in demand. Therefore the estimate of $20 per horsepower year is considerably less than that which might reasonably be expected.

RESERVOIRS ON THE KANAWHA RIVER.

The basin of Kanawha River is 11,000 square miles in extent. The river itself is subject to wide fluctuation in stage and the floods are somewhat severe. There have been identified in the Kanawha basin reservoir sites of total capacity sufficient to absolutely conserve the runoff from 6,080 square miles, which is 55% of the entire drainage area. The effect of this conservation on floods will be to reduce their heights by more than an equivalent proportion.

The effect of such a system of reservoirs on navigation in the Kanawha is important. The present project for improvement of navigation provides for the maintenance of a 6-ft. depth along the lower 96 miles of the river. For the first 79 miles this is accomplished during low-water by eight movable dams and for the remainder of the distance by two fixed dams. These dams have been erected at an expenditure of $1,124,526, and $657,000 have been expended for care and operation, this expense increasing annually. Proper manipulation of storage from these reservoirs would produce along the present canalized portion, without the aid of the movable dams, increased depths, as shown in the following table:

SECTION ABOVE LOCK NO. 6.

Increase of stage, ft.	1.0	2.0	3.0	4.0	5.0	6.0	7.0
Flow required cu. ft.	1,570	3,420	5,680	8,400	11,400	14,800	18,300
Reservoirs:	(—Duration of Stage (Days).—)						
Full	1,860	850	514	347	256	197	160
¾-Full	1,400	640	380	260	192	148	120
½-Full	930	425	257	174	128	98	80

SECTION BELOW ELK RIVER.

(About 2½ miles above Lock No. 6.)

Increase of stage, ft.	1.0	2.0	3.0	4.0	5.0	6.0	7.0
Flow required, cu. ft	700	1,630	2,650	3,710	5,000	6,400	8,000
Reservoirs:	(—Duration of Stage (Days).—)						
Full	4,170	1,790	1,100	790	580	460	365
¾-Full	3,100	1,340	830	590	440	340	270
½-Full	2,085	895	550	395	290	230	182

From the above table it will be seen that the storage proposed on the upper drainage area of Kanawha River is sufficient to prolong in the steepest section an additional 7-ft. stage for a period of 160 days with reservoirs full, or 120 days with reservoirs three-quarters full, while at the section below the mouth of Elk River the effect is far more marked. The additional discharge of 8,000 cu. ft. per second raises the stage 7 ft. The possibilities along this portion of the river for maintenance of navigable stage by the release of stored waters are so great that it appears that the installation of the slack-water system was unnecessary throughout the portion in which movable dams have been installed.

Kanawha River basin is capable of great development for water power. The total minimum indicated power along the river and its tributaries, resulting from a recent survey, is shown as 335,000 HP., which, with the installation of the proposed storage system would be enormously increased. For example, if this stored water were equally distributed over an entire twelve months there would be available along the main stem of the Kanawha and New rivers an indicated horsepower of 465,000, in addition to that

TABLE II.—SELECTED RESERVOIR SITES IN THE MONONGAHELA RIVER BASIN.

Stream and location.	Catchment area above reservoir, sq. mi.	Mean annual flow from catchment area in second feet.	Capacity of reservoir in sq. mi. of catchment area.	Capacity of reservoir 1,000,000 cu. ft.	Height of dam feet.	Area of flow line in acres.
Dunkard Creek, Cass Co., W. Va.	160	270	150	8,300	100	[illegible]
Buffalo Creek, Mannington, W. Va.	40	70	40	2,400	59	[illegible]
Booths Creek, Monongah, W. Va.	40	70	40	2,800	101	[illegible]
Sandy Creek, Grafton, W. Va.	80	140	80	6,200	155	[illegible]
Teter Creek, Nestorville, W. Va.	40	60	40	2,600	115	[illegible]
Elk Creek, Clarksburg, W. Va.	100	170	100	5,900	92	[illegible]
West Fork River, Clarksburg, W. Va.	380	640	380	24,700	109	[illegible]
Buckhannon River, Buckhannon, W. Va.	310	530	310	18,800	77	[illegible]
Middle Fork, Tygart, Barbour Co., W. Va.	140	230	140	8,100	107	[illegible]
Cheat River, Tucker Co., W. Va.	820	1,400	440	23,800	200	[illegible]
Tygart River, Beverly Co., W. Va.	330	560	330	19,100	142	[illegible]
Tenmile Creek, Millsboro, Pa.	310	527	283	15,200	180	[illegible]
Whitely Creek, Mapletown, Pa.	66	112	69	3,690	140	[illegible]
Youghiogheny River, Friendsville, Md.	270	690	255	20,270	240	[illegible]
Deep Creek, Garrett Co., Md.	55	136	58	4,603	83	[illegible]
Cherry Creek, Garrett Co., Md.	55	136	62	4,912	64	[illegible]
Muddy Creek, Garrett Co., Md.	13	32	13	1,065	70	[illegible]
Herrington Creek, Garrett Co., Md.	13	32	11	900	60	[illegible]

TABLE I.—SELECTED RESERVOIR SITES IN THE ALLEGHENY RIVER BASIN.

Stream and location.	Catchment area above reservoir, sq. mi.	Mean annual flow from catchment area in second feet.	Capacity of reservoir in sq. mi. of catchment area.	Capacity of reservoir 1,000,000 cu. ft.	Height of dam feet.	Area of flow line in acres.
Conewango R., E. of Jamestown, N. Y.	290	560	275	17,500	38	24,000
Chautauqua Lake	190	3' on surface	27	1,740	..	13,400
French Creek, Marvin, N. Y.	86	148	86	5,677	75	4,700
Dodge Creek, Portville, N. Y.	46	92	46	2,990	100	1,800
Haskell Creek, Olean, N. Y.	30	60	30	1,950	70	1,320
Mahoning Creek, Mahoning, Pa.	370	636	370	22,100	251	5,300
Cowanshannock Cr., Valley Co., Pa.	48	82	48	2,720	118	1,390
Buffalo Creek, S. W. N. Buffalo Co., Pa.	80	138	80	5,120	149	2,260
Clarion River, Clarion, Pa.	990	1,700	436	23,850	210	6,920
Loyal Hanna, Sallsburg, Pa.	260	472	58	3,180	98	2,200
Crooked Creek, Burrell Co., Pa.	200	340	200	12,415	110	7,800
Twolick Creek, Homer, Pa.	68	116	52	2,860	122	1,300
Yellow Creek, Homer, Pa.	66	112	66	3,900	150	1,620

TABLE III.—SELECTED RESERVOIR SITES IN THE KANAWHA RIVER BASIN.

Stream and location.	Catchment area above reservoir, sq. mi.	Mean annual flow from catchment area in second feet.	Capacity of reservoir in sq. mi. of catchment area.	Capacity of reservoir 1,000,000 cu. ft.	Height of dam feet.	Area of flow line in acres.
[illegible]er River, Pocahontas Co., W. Va.....	320	460	320	16,300	177	4,700
[illegible]er, Clay Co., W. Va.....	940	1,350	940	49,900	190	15,700
[illegible]er River, Lewisburg, W. Va.....	680	980	680	32,900	164	11,600
[illegible] River, Greenbrier Co., W. Va.....	180	250	180	8,000	80	7,000
[illegible]y Creek, Nicholas Co., W. Va.....	60	90	60	3,400	74	2,600
[illegible] Creek, Kanawha Co., W. Va.....	60	90	60	3,300	97	2,300
[illegible] River, Fayette Co., W. Va.....	1,290	1,860	780	35,900	250	7,500
[illegible] River, above mouth Greenbrier River...	3,600	5,750	390	20,300	135	8,000
[illegible] Creek, Giles Co., Va.....	310	620	100	6,550	110	3,000
[illegible] River, Radford, Va.....	1,740	3,500	920	59,400	125	23,000
[illegible] Creek, Wythe Co., Va.....	250	510	100	6,400	100	4,500
[illegible] Island Creek, Pulaski Co., Va.....	380	770	60	4,000	100	2,800
[illegible] Creek, Wythe Co., Va.....	180	370	40	2,900	100	2,000
New River, Carrol Co., Va.....	1,290	2,600	300	19,400	200	6,200
[illegible] Creek, Putnam Co., W. Va.....	60	80	60	4,000	63	2,300
[illegible] Creek, Mason Co., W. Va.....	80	100	80	3,400	61	2,000
[illegible]aligo River, Putnam Co., W. Va.....	230	300	110	4,700	65	3,900
Coal River, Kanawha Co., W. Va.....	890	1,250	900	40,580	128	20,800

now available, during the low-water season, the value of which, based on a rental of $20 per horsepower year would be $9,300,000 annually, equivalent to a 3% income on $310,000,000.

The location of these proposed reservoirs and facts concerning them are set forth in Table III.

[Mr. Leighton then takes up, in a similar way to that pursued above, the Little Kanawha and Big Sandy rivers, the Kentucky, Licking, Scioto and Great Miami rivers, and the Cumberland River, which space compels us to omit.—Ed.]

RESERVOIRS ON THE TENNESSEE RIVER.

The Tennessee River has a drainage area amounting to 39,000 square miles. The character of its basin varies from the mountainous portions in the Appalachian region to the flatter country extending across the western end of Kentucky. It is a river subject to great amplitude in river stage due to descending floods which have in the past been extremely destructive to property, and especially to agricultural land.

Tennessee River forms a system of internal waterways, capable of being navigated more than 1,300 miles by steamboats. In the year 1904 the tonnage amounted to 1,607,000 tons, valued at $30,000,000. Improvements on the river up to June 30, 1905, amounted to $7,178,000. The government projects are considered in three sections, first that part of the river lying above Chattanooga, Tenn., second that part lying between Chattanooga and Riverton, Ala., and third, that part from Riverton to the mouth.

Under the present project it is the intention to develop a mean low-water depth of 3 ft. in the first section. This, of course, even if it were successful, would not encourage any great amount of water transportation along this stretch of the river, because under modern transportation conditions small draft boats cannot be operated with profit. Along the second section navigation is possible from six to nine months of the year only. There are shoals in the river which have been overcome or are in process of being overcome by government canalization. On the lower section of the river there is a moderate and uniform slope, with original low-water depth of about 3.5 ft. over the lower 196 miles and 2 ft. over the remainder of the distance up to Riverton. The present government project is to obtain by dredging a channel not less than 5 ft. deep at mean low-water.

The prospects for power development, especially in the highland portions of the river, are enormous. The minimum indicated power developed by the low-water flow of the river and its tributaries is over 1,000,000 HP. The profitable development would be far greater than this, while if the system of storage reservoirs available for construction were erected the power would be increased from twelve to fifteen times.

Available reservoir sites in the portions of the river basin that have been surveyed will conserve the entire annual flow from 12,520 square miles of drainage area, or 32% of the entire drainage area of the Tennessee. Were these reservoirs constructed, the effect on floods in this river would be to reduce them by a far greater per cent. than that above stated. The reservoirs practically cover the upland areas, and the contrast between this and the remaining portion of the area is especially marked.

The effect of the regulated discharge of the stored water above indicated will be shown along three broad sections of the river, the first at Knoxville, the second at Chattanooga and the third below Riverton. The facts given will represent the three sections of the river along which improvement has been attempted and, although the total storage above described is not advocated for purposes of navigation, the effects of the same in increasing the stage of the river during low-water seasons will be set forth in Table IV., which are similar to those already given.

The facilities for reservoir construction in the basin are set forth in Table V.

Facts concerning reservoir facilities of the various tributaries of the Ohio have now been given. It should be noted that the information concerning some of the tributaries is not complete and that some of the large tributaries are not represented. The greater part of the area covered lies to the south of the Ohio, while surveys of the northern tributaries are somewhat sparse. For this reason it has been necessary to omit from consideration large affluents of the Ohio, like the Wabash and Muskingum, while the Scioto and Miami are practically without representation. The consideration of floods on the Ohio will proceed without them, and if it can be shown that the incomplete reservoir system heretofore presented will abate floods in the Ohio the efficiency of the system and the integrity of the principle will have been demonstrated.

The Influence of Reservoirs on Flood Stages in the Ohio River at Various Points.

All floods on the Ohio do not have a common origin. At times they arise in the upper part of the river and by the time they have reached the lower portion have become so flattened out that they cause no damage or apprehension. Again, floods sometimes visit the region of Evansville and Paducah which have not caused alarm in the vicinity of Pittsburg and Wheeling. Of course, it is true that whenever a flood descends from the upper tributaries its effect is traceable throughout the length of the river, but its magnitude may not be such as to approach the danger line in the lower part of the stream. The two greatest floods during the last quarter of a century occurred in 1884 and 1907. Those which occurred in the intervening period, while serious in themselves, are not important in comparison with the two great floods above mentioned. Available records of the flood of 1884 are not satisfactory except for the main stream at Wheeling and at Paducah. We can secure from these two series of records a very good idea of the progress of the flood, but information concerning the contributary area is entirely lacking.

Both the floods of 1884 and 1907 were above the danger line at Wheeling for a period of five days. The greatest height of the earlier flood was 51.5 ft. on the Wheeling gage, while that of the later flood was 48.9. The difference was so slight that in computing the effect of storage either might be used as a maximum, but, inasmuch as we are fully acquainted with the conditions during the flood of March, 1907, it will be used to test the efficiency of the proposed storage system. There will also be included the flood of January, 1907. These two floods were entirely different in their effects and progress. The flood of January did the greatest damage in the lower portion of the river, while that of March arose in the upper portion of the basin, principally in the Monongahela drainage area, and did its greatest damage there. They will, therefore, serve as excellent types upon which to base an opinion of the reservoir system as a means of preventing floods. We will therefore, consider these two floods in turn, starting at Pittsburg and ending at Cairo, for the purpose of showing what would

TABLE IV.—EFFECT OF STORED WATER IN RAISING LOW WATER STAGE IN THE TENNESSEE RIVER.

SECTION AT KNOXVILLE.										
Increase of stage, ft.....	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
Flow required, cu. ft.....	970	3,220	6,380	9,930	13,700	17,670	21,840	26,210	30,780	35,300
Reservoirs:				Duration of Stage (Days).						
Full	4,250	1,280	647	416	300	233	189	157	134	117
¾-Full	3,187	960	485	312	225	174	142	117	100	87
½-Full	2,125	640	323	208	150	116	95	78	67	58
SECTION AT CHATTANOOGA.										
Increase of stage, ft.....	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
Flow required, cu. ft.....	2,780	6,540	11,040	16,000	25,580	27,870	34,470	41,070	47,670	54,270
Reservoirs:				Duration of Stage (Days).						
Full	2,890	1,230	728	502	314	288	233	196	168	148
¾-Full	2,167	922	546	376	160	216	174	147	126	111
½-Full	1,445	615	364	251	157	144	116	98	84	74
SECTION BELOW RIVERTON.										
Increase of stage, ft....	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
Flow required, cu ft....	1,440	4,200	7,600	11,500	15,900	20,800	26,000	31,600	37,500	43,600
Reservoirs:					Duration of Stage (Days).					
Full	5,600	1,900	1,060	700	500	390	310	250	210	180
¾-Full	4,200	1,430	790	520	380	290	230	190	160	138
½-Full	2,800	950	530	350	250	195	155	125	105	90

TABLE V.—SELECTED RESERVOIR SITES IN THE TENNESSEE RIVER BASIN.

Stream and Location.	Catchment area above Reservoir sq. mi.	Mean annual flow from Catchment area in second feet	Capacity of Reservoir in sq. mi. of catchment area	Capacity of Reservoir 1,000,000 cu. ft.	Height of Dam Feet	Area of Flow line in Acres
Clinch River, Scott Co., Va.....	780	1,080	600	30,400	180	10,000
N. Fork, Holston River, Scott Co., Va.....	340	470	200	8,700	90	6,700
S. Fork, Holston River, Sullivan Co., Tenn....	560	770	560	26,200	171	8,700
Holston River, Hawkins Co., Tenn.....	2,610	3,260	2,610	111,200	146	44,000
Nolichucky River, Greenville, Tenn.....	940	1,590	270	14,700	100	10,200
Clinch River, Sneedville, Tenn.....	560	770	390	18,500	100	8,500
Powell River, Jonesville, Va.....	570	790	380	17,100	100	12,000
Holston River, N. E. of Knoxville, Tenn.....	3,400	5,300	3,300	163,500	160	49,000
French Broad River, E. of Knoxville, Tenn....	4,050	6,300	4,000	199,600	200	70,000
Little River, S. of Knoxville, Tenn.....	290	450	290	17,400	94	12,100
Little Tennessee River, Loudon Co., Tenn....	2,520	7,000	860	78,000	100	54,400
Little Tennessee River, Swain Co., Tenn.....	380	1,050	80	7,340	100	5,120
Clinch River, Roane Co., Tenn.....	2,110	2,900	900	26,500	60	30,000
Cheoah River, Graham Co., N. C.....	180	500	75	6,700	150	2,840
Hiwassee River, Cherokee Co., N C.....	550	1,450	380	32,400	200	11,080
Nottely River, Union Co., Ga.....	240	410	20	1,000	40	1,680
Toccoa River, Fannin Co., Ga.....	240	510	60	4,130	100	2,880
Hiwassee River, Hiwassee, Ga.....	100	260	40	2,240	100	1,600
Tennessee River, Rabun Co., Ga.....	50	220	20	2,720	50	3,800
Hiwassee River, near mouth, Tenn.....	2,040	4,300	1,130	77,500	70	70,000
W. Chickamauga Cr., Walker Co., Ga.....	80	100	80	5,260	60	6,300
S. Chickamauga Cr., Catoosa Co., Ga.....	110	220	100	6,330	60	7,400
Sequatchie River, Sequatchie Co., Tenn.....	330	660	60	4,000	50	5,500

TABLE VI.—ESTIMATED EFFECT ON FLOODS OF JANUARY AND MARCH, 1907, AT PITTSBURG, PA. DANGER LINE 22 FT., EQUIVALENT TO FLOW OF 214,000 SEC. FT.

Day.	Flood of January. Effect without Conservation.		Probable Effect with Conservation.		Day.	Flood of March. Effect without Conservation.		Probable Effect with Conservation.	
	Gage Height.	Discharge sec. ft.	Discharge sec. ft.	Gage Height.		Gage Height.	Discharge sec. ft.	Discharge sec. ft.	Gage Height.
19	21.4	205,000	142,000	16.6	13	12.7	98,000	71,000	11.
20	23.2	230,000	160,000	18.0	14	30.8	344,000	249,000	24.5
21	18.8	170,000	118,000	14.5	15	35.1	412,000	298,000	27.7
					16	22.8	225,000	163,000	18.2
					17	15.7	131,000	95,000	12.5

have been the effect had the reservoir system proposed in previous pages actually been installed and in operation at that time.

Records show that floods never arise over the entire Ohio basin at one time. So far, only one-quarter to one-third of the total area has been involved in any flood. Should all the basin be involved simultaneously, the damage would be beyond computation, in the lower Mississippi as well as in the Ohio, and all human efforts at abatement would be ineffectual. This, of course, is true in any large basin; our past, present and future safety lies in the fact that only small portions of any large basin are in flood simultaneously. We can provide protection for only these partial floods, but the partial protection is quite worthy of accomplishment.

AT PITTSBURG, PA.—The drainage area of the Ohio River above Pittsburg, Pa., is 18,800 square miles, while the area studied for conservation is 4,575 square miles, or about 25% of the entire area. The course of the two floods and the computed effect of storage are given in Table VI.

During the January flood at Pittsburg 67% was derived from the Monongahela. It will be noted in the table that this flood would not have reached the danger line had the storage system been installed. In the March flood, 45% of the water came down the Allegheny, in which basin, as has already been explained, surveys showing all the reservoir possibilities have not been made. Were these surveys available, the additional reservoir sites that they would reveal would, if included in the estimate, materially reduce this percentage. The table shows that, with the storage now identified, the March flood would have reached a height of 5.7 ft. above the danger line, instead of the 13 ft. which actually occurred. It should be recalled that the reservoirs included in the above estimate conserve the torrential flow, as previously explained, so that the method of proportionate estimate used here does not do justice to the efficiency of the proposed system. Again, it should be recalled that the full economical storage capacity in the Allegheny has not been included in the estimates. Were it possible to make use of these two important factors, it would be demonstrated that the March flood would not have arisen to the Pittsburg danger line. The small flow in excess of the danger line flow would readily be dispersed with either factor.

[Mr. Leighton then proceeds by the same method to compute the effect of the proposed reservoirs on flood heights at various points on the Ohio River, viz., Wheeling, Parkersburg, Point Pleasant, Huntington, Catlettsburg, Portsmouth, Maysville, Cincinnati, Madison, Louisville, Evansville, Paducah, and Cairo, Ill., where the Ohio joins the Mississippi. Space obliges us to include only the statements regarding flood heights at Cincinnati and Paducah.—Ed.]

AT CINCINNATI, O.—We come now to a consideration of floods at Cincinnati, O., above which there is in the Ohio basin a drainage area of 73,900 square miles. Of this, the present report proposes to conserve 20,100 square miles, or 27% of the whole. Licking River, a tributary basin, 3,870 square miles in extent, enters the Ohio from the south just above Cincinnati. The present report provides for the complete conservation of 590 square miles of the Licking basin. During the floods of 1907 the average runoff from the Licking River was, for a period of ten days in each case, 21,000 cu. ft. per second. The maximum was much higher than this. This unrestrained discharge on the top of an already gorged channel aggravated the conditions at Cincinnati. The Great Miami, too, was a factor. Although it enters the Ohio below Cincinnati, its enormous discharge of water during this flood had a backwater effect and caused a higher stage at Cincinnati than would have occurred had the Miami been properly conserved.

The danger line at Cincinnati is 50 ft. on the gage, equivalent to a flow of 415,000 cu. ft. per second. This is a low danger line, representing less channel capacity than the danger lines at Maysville and Catlettsburg on the river above. The effect of the floods on the river and the effect of storage according to the system proposed would be as shown in Table VII.

According to the computations in the above table, the reservoir system would have reduced the January flood to a total period above the danger line of five days and a maximum height of 53.3 ft., or 3.3 ft. above the danger line, while the March flood would have been reduced somewhat more. Here again we are obliged to urge consideration of the factors that are left out of account in these computations. Utilization of all the conservation facilities on the drainage area above, and a proper accounting for the fact that it is the torrential flow that would be conserved, would in actual practice reduce the gage height as shown by this proportional computation below the danger line. How far below we do not know, but a fair-minded consideration of the matter will show that it would be well down to the point of safety.

Concerning the flatter portion of the Ohio River below Louisville, certain observations must be made with respect to the behavior of floods. It is well understood that the lower the slope of any river the more pronounced will be the backwater effects of any tributary entering that river. Four great rivers and several smaller, though important, ones enter this flat portion of the stream below Louisville, namely, the Wabash, the Cumberland, the Green and the Tennessee. When they pour their great floods into the lower Ohio their effect is to gorge the channel and back the water up to the foot of the falls at Louisville. In other words, if a flood comes out of the Wabash, Cumberland, Green or Tennessee rivers into the lower Ohio, the effect is almost as plainly marked for long distances above the point of confluence as it is below. Now, in estimating the effects of the reservoirs in the proposed system on the flood height at Evansville, Ind., for example, we cannot take into account conservation on the Tennessee, Cumberland, Green and Wabash rivers, but must confine estimates to those on the tributaries above Evansville. Nevertheless, it will readily be appreciated that, were these four great streams well conserved, the effect would be to markedly reduce the floods in the Ohio River above their points of entrance. The estimates for Evansville and Mount Vernon are therefore given without taking account of such effects.

AT PADUCAH, KY.—The next point is Paducah, Ky., between which and Mount Vernon, Ind., enter the Wabash, Tennessee and Cumberland rivers. We have not the benefit of surveys on the Wabash, and therefore must leave it out of consideration here. The Cumberland is also only partially surveyed, and, while figures are shown to be available 2,380 square miles that may absolutely be conserved, it does by no means represent the highest development of conservation on the river. The Tennessee River has an area that may be conserved of 12,520 square miles. Therefore, we have in the station at Paducah, Ky., the effect of a completely conserved river in the Tennessee, partially conserved in the Cumberland, and wild rivers in the Wabash and Green. The danger line at Paducah is 40 ft., equivalent to a flow of 830,000 cu. ft. per second. The record of the floods of 1907, and the effect of such storage facilities as have been identified, are set forth in Table VIII.

CONCLUSIONS CONCERNING FLOOD ABATEMENT.—In the foregoing pages the effect of conservation reservoirs in reducing the height of floods at numerous points along the Ohio, from Pittsburg to Cairo, has been reviewed. In making the computations of such effects certain legitimate allowances favorable to the conservation scheme have purposely been omitted. The test of the reservoirs has been made without giving them the advantage of these allowances in the computations. Occasional reference has been made to them in the text. It has been necessary to include rivers on which no information concerning conservation possibilities is obtainable and other rivers concerning which such information is not complete. Advantage has not been taken in the computations of the fact that the proposed reservoirs will conserve the torrential flow from each basin and leave unregulated the lower and more moderate portions. The figures have been based solely on proportionate areas, conserved and unconserved. All these disadvantages have been accepted freely and the test has been applied to the conditions arising in two floods along the Ohio, the greatest, with one exception, in a quarter of a century. What are the results?

It has been shown that the flood height in all cases would be either reduced below the danger line or would exceed the danger line by so small an amount that the use of any one of the allowances above mentioned would give complete abatement throughout the length of the river. It is impossible to draw any other conclusion from the data presented. The possibilities of prevention of floods by conservation reservoirs are shown in a clear and striking manner and they merit at least further consideration and examination as a part of the proposed government policy with reference to inland waters.

Effect of Storage on Navigation.

In the previous pages the effects of withholding a part of the flood waters from the Ohio River during flood season have been considered. We will now consider the effects of allowing this water to discharge into the river during low-water seasons for the benefit of navigation. For this purpose sections along the river have been selected, and the effect of the discharge of stored water under varying conditions has been computed. For the sake of brevity, no attempt will be made here to explain the interesting methods by which such results were arrived at, but the

TABLE VII.—ESTIMATED EFFECT OF STORAGE ON FLOODS OF JANUARY AND MARCH, 1907, AT CINCINNATI, OHIO. DANGER LINE 50 FT., EQUIVALENT TO A FLOW OF 415,000 SEC. FT.

Day.	Flood of January. Effect without Conservation.		Probable Effect with Conservation.		Day.	Flood of March. Effect without Conservation.		Probable Effect with Conservation.	
	Gage Height.	Discharge sec. ft.	Discharge sec. ft.	Gage Height.		Gage Height.	Discharge sec. ft.	Discharge sec. ft.	Gage Height.
15	47.2	375,000	272,000	39.7	13	41.0	290,000	220,000	35.5
16	51.1	430,000	311,000	42.6	14	50.3	420,000	318,000	43.1
17	55.7	500,000	362,000	46.2	15	54.1	475,000	360,000	46.0
18	59.4	560,000	405,000	49.2	16	57.6	530,000	401,000	48.9
19	61.9	595,000	435,000	50.9	17	60.2	570,000	431,000	51.0
20	64.1	630,000	456,000	52.6	18	61.6	590,000	447,000	52.0
21	65.1	645,000	466,000	53.3	19	62.1	600,000	455,000	52.6
22	64.6	640,000	463,000	53.1	20	61.3	590,000	447,000	52.0
23	63.2	615,000	445,000	51.9	21	59.8	565,000	428,000	50.8
24	61.2	585,000	423,000	50.5	22	57.5	530,000	401,000	48.9
25	58.1	540,000	391,000	48.2	23	54.8	490,000	371,000	46.8
26	54.0	475,000	344,000	44.9	24	52.3	450,000	341,000	44.7
27	48.0	390,000	282,000	40.5	25	49.4	405,000	307,000	42.2

TABLE VIII.—ESTIMATED EFFECT OF STORAGE ON FLOODS OF JANUARY AND MARCH, 1907, AT PADUCAH, KY. DANGER LINE 40 FT., EQUIVALENT TO A FLOW OF 830,000 SEC. FT.

Day.	Flood of January. Effect without Conservation. Gage Height.	Effect without Conservation. Discharge sec. ft.	Probable Effect with Conservation. Discharge sec. ft.	Probable Effect with Conservation. Gage Height.	Day.	Flood of March. Effect without Conservation. Gage Height.	Effect without Conservation. Discharge sec. ft.	Probable Effect with Conservation. Discharge sec. ft.	Probable Effect with Conservation. Gage Height.
21	39.7	820,000	664,000	35.3	20	39.8	820,000	654,000	35.0
22	41.0	867,000	702,000	36.4	21	40.7	856,000	683,000	35.9
23	42.3	923,000	748,000	37.7	22	41.4	885,000	705,000	36.6
24	43.4	970,000	786,000	38.7	23	41.9	905,000	721,000	37.0
25	44.3	1,008,000	819,000	39.6	24	42.2	918,000	732,000	37.3
26	45.0	1,036,000	839,000	40.2	25	42.3	923,000	736,000	37.4
27	45.6	1,062,000	860,000	40.7	26	42.2	918,000	732,000	37.3
28	45.7	1,065,000	864,000	40.9	27	42.0	910,000	725,000	37.1
29	45.6	1,062,000	860,000	40.7	28	41.5	890,000	710,000	36.7
30	45.3	1,048,000	849,000	40.5	29	40.7	856,000	682,000	35.9
31	44.8	1,028,000	833,000	40.1	30	39.7	820,000	654,000	35.0
Feb.									
1	44.3	1,008,000	818,000	39.6					
2	43.3	958,000	776,000	38.4					
3	42.3	923,000	748,000	37.7					
4	41.4	883,000	715,000	36.8					
5	40.2	837,000	678,000	35.7					
6	38.7	783,000	634,000	34.3					

facts will be given in Table IX. The first column of the table, entitled "Increase of Stage, feet," means the amount that the stage would be increased above the low-water stage. The second column, entitled "Flow Required," is merely a rating of the section showing what amount of water would be necessary to increase the stage at said section a stated number of feet. The last three columns in the table give the number of days that the flow from the reservoirs would maintain a stated increase of stage, the figures being based on full, three-quarters full and half-full reservoirs. This latitude of reservoirs is included because it is conceivable that there are some years during which the reservoirs would not be completely filled, although it is hardly conceivable that there would be any year that they would not be considerably more than half full.

Assuming now that the low-water period is three months or ninety days long, the Pittsburg table shows that, with full reservoirs, an additional 4-ft. stage could be maintained at Pittsburg for 87 days, or practically the three months. Of course, in the actual manipulation of such reservoirs, they would not be called upon to deliver their water in this way. To maintain a certain stage in the river it would be necessary to start with only a small amount of water, because the ordinary stage of the river would depart from the required stage only gradually, and this amount of water necessary to maintain that stage would therefore increase to the maximum. The facts at command and the space in this report are not sufficient to permit the making of a critical estimate of this amount. Therefore, the figures in the following table are given in their present form merely to show the great possibilities of assisting navigation with stored water. The final working out of the matter involves considerable labor as well as the minute study of the channel capacity from Pittsburg to Cairo.

TABLE IX.—Increase of Stage of Ohio River and Duration of Same at Stated Sections, Resulting from Release of Stored Waters during the Low-Water Season.

PITTSBURG, PA.

Increase of Stage Feet	Flow Required Second Feet	Duration of Stage (Days) Reservoirs Full	Reservoirs ¾-Full	Reservoirs ½-Full
1.0	6,400	407	305	203
2.0	13,600	191	143	96
3.0	21,400	121	91	60
4.0	29,700	87	66	44
5.0	38,400	68	51	34
6.0	47,400	55	41	27

POINT PLEASANT, W. VA.

Increase of Stage Feet	Flow Required Second Feet	Duration of Stage (Days) Reservoirs Full	Reservoirs ¾-Full	Reservoirs ½-Full
2.0	11,600	718	539	359
4.0	24,100	346	259	173
6.0	37,800	220	165	110
8.0	52,300	159	119	80
10.0	67,300	124	93	62
12.0	82,300	101	76	50

CINCINNATI, OHIO.

Increase of Stage Feet	Flow Required Second Feet	Duration of Stage (Days) Reservoirs Full	Reservoirs ¾-Full	Reservoirs ½-Full
2.0	8,800	1,262	947	631
4.0	18,300	607	455	304
6.0	29,500	377	282	188
8.0	41,800	266	200	133
10.0	55,000	202	152	101
12.0	69,300	160	120	80
14.0	84,300	132	99	66
16.0	99,300	112	84	56
18.0	114,300	97	73	49

PADUCAH, KY.

Increase of Stage Feet	Flow Required Second Feet	Duration of Stage (Days) Reservoirs Full	Reservoirs ¾-Full	Reservoirs ½-Full
2.0	23,000	1,068	801	534
4.0	52,000	414	310	207
6.0	81,000	266	200	133
8.0	111,000	196	147	98
10.0	141,000	153	114	76
12.0	171,000	126	94	63
14.0	201,000	107	81	54
16.0	232,000	93	70	46
18.0	266,000	81	61	40

The facts in the above table indicate that while it is not possible to maintain a 9-ft. stage from Pittsburg to Cairo with reservoirs alone, such stage can be maintained along the flatter portions of the river, especially those below Huntington, W. Va., except at steep points like the Louisville Falls, where canalization is necessary.

These facts are particularly important in view of the report of the Advisory Board of Engineers concerning future navigation improvements on the Ohio River, which has recently been presented. The author of the present report is not informed concerning the specific recommendations made by said board, but, in view of the showing made in the above table, he contends that no settled policy with reference to navigation improvements in the Ohio should be determined on until these possibilities are taken into account.

Of course, it will be necessary to canalize, especially in the upper portion of the river; but, it is claimed, as a result of these investigations, that it is unnecessary to place a continuous line of locks and dams from the head to the foot of the river in order to ensure a 9-ft. stage at all periods of the year. The money that would be expended on some of these locks and dams might be used to better purpose in the highland tributaries of the river for the construction of storage reservoirs.

Having now considered the possibilities of conservation in that portion of the drainage area of Ohio River which has been properly surveyed, and the effect of this conservation on floods and navigation in the Ohio, let us consider whether or not the scheme is experimental or whether, after all, the effects have been actually demonstrated in practice.

There is in Russia, at the head of the Volga and Msta rivers, a great system of reservoirs that is devoted to purposes of flood prevention and the maintenance of low-water navigation. The two rivers have their sources in the same region but flow in opposite directions. The country is flat and wooded and dotted with numerous lakes which provide excellent facilities for storing flood waters. A great reservoir system, therefore, was developed by the government, an excellent description of which, together with its effects, appears in the report of Major H. M. Chittenden, U. S. Engineers, entitled "Reservoir Sites in Wyoming and Colorado," House Document No. 141, Fifty-fifth Congress, second session, pages 36 and 37, from which the following extracts are taken:

These reservoirs store about 35,000,000,000 cu. ft. of water in all, of which 20,000,000,000 can be used in the Volga and 20,000,000,000 can be turned in the other direction, there being apparently a storage of about five or six billions that can be used in either direction. The largest and most important of these reservoirs, and one of the largest in the world in point of capacity, although insignificant in depth and containing dam, is the Verkhnevoljsky Reservoir. So slight is the fall of the stream in this region that, although the dam produces a maximum elevation of water surface at its site of only about 17.5 ft., the water backs up a distance of about 60 miles and includes several lakes. The low-water season capacity of this reservoir is about 14,000,000,000 cu. ft., and the average season storage is much greater. Its effect upon the low-water flow of the river below the dam is to raise its normal surface 2.8 ft. at Rjef, 96 miles below; 1.4 ft. at Tver, the mouth of the Tvertsa, 212 miles below, and 0.14 ft. at 410 miles below. At the mouth of the Tvertsa the storage of the Zavodsky Reservoir comes in and helps out navigation below. The total navigable distance on the Volga over which the beneficial influence of these reservoirs is felt is upward of 450 miles.

On the Msta slope there are no fewer than 10 important reservoirs, all of them being on the sites of natural lakes, the total storage aggregating about 14,000,000,000 cu. ft. As already stated, about 6,000,000,000 cu. ft. of storage which really lies on the Volga slope, including the Zavodsky reservoir, formerly was and still can be turned into the Baltic drainage. This entire system of summit reservoirs that can be used to feed the Msta is called the Vychnevolotsky system. It affords material improvement to the navigable condition of Msta and Volkhoff rivers during the period of low water.

The system of reservoirs just described is certainly a great success, and upon it much of the prosperity of the surrounding country depends. It is probably the most complete example in the world of the joint results of flood prevention and the improvement of navigation produced by artificial reservoirs. It has an importance, however, which it could not have in this country, even with equal physical advantages, for railroads here do a far greater proportion of the transportation business than in Russia. But the example shows how far favorable natural conditions can be made to improve the low-water conditions of streams.

For a partial demonstration of the effectiveness of the reservoir method, reference is made to the conditions at the head of Mississippi River. Here only a part of the possible reservoir development has been made, but even this appears to have been eminently successful, as may be shown by a reading of the report of a board of United States engineers, consisting of Major H. M. Chittenden, Major Charles L. Potter and Captain W. B. Judson (Report of Chief of Engineers, U. S. A., 1906). If anything, in addition to that which has been given in previous pages, is needed to prove the usefulness of reservoir systems, a perusal of this report will fulfill all demands. Here is a system constructed primarily for the benefit of navigation; flood prevention was not contemplated, yet the success of the system in preventing floods, save in a few particular and unusual situations, is as great as the success in navigation.

The five reservoirs making up this system have a total capacity of over 90,000,000,000 cu ft., and will conserve the annual flow from 4,250 square miles of drainage area, except in extremely wet years. In fact, during only one year in the past twenty has there been sufficient runoff to more than fill these reservoirs. The effects on navigation are unmistakable, and by a further development of the storage facilities in the states of Minnesota and Wisconsin the capacity could probably be increased to 175,000,000,000 cu. ft. Therefore, the effects of these reservoirs, as beneficial as they are shown to be along the Mississippi in Minnesota, do not represent the highest possibility of such development.

With reference to their usefulness in preventing floods: objection has been made that their effect is almost inappreciable at St. Paul and totally obliterated at Lake Pepin. This might have been predicted from the first. The reservoirs conserve only 11.8% of the total drainage area above St. Paul and therefore, broadly speaking, the severity of the floods at St. Paul will be decreased only in like proportion. There is a drainage area between the reservoirs and St. Paul sufficiently large to provide at times a flood-producing runoff. Of course, this also remains true for the river below St. Paul; at Winona, Minn., for example, the proportion of conserved area to the total drainage area is only 7.3%. Therefore, the complaint above noted ap-

pears to arise from a lack of consideration of the facts.

No one expects to obliterate floods if only 11 or 12% of the area is under control. This is well illustrated by the statement of the engineering board above mentioned in its demonstration that the reservoir system was not responsible for the great flood of 1905 at Aitkin, Minn. The following quotation is pertinent:

> In the first place, it may be stated that the drainage area above Pine Knoll, excluding that of the four reservoirs above Aitkin, is large enough to produce a flood at Aitkin in times of excessive rainfall if not a drop of water were coming from the reservoirs. This area is about 2,250 sq. mi., and includes several streams like the Prairie, Swan and Willow rivers. To produce a high flood, say 12,000 cu. ft. per second at Aitkin, would require only about 5 cu. ft. per second per sq. mi., a figure undoubtedly reached in times of heavy and continuous rainfall. (Report of Chief of Engineers, 1906, Part 2, page 1459).

Cost of the Reservoir System.

It will be impossible to give precise data concerning the cost of the proposed conservation system. Such an estimate would require a minute examination of all the physical conditions and a valuation of the property to be submerged. Relative figures, based upon the cost of construction of similar reservoirs in other places, are the best that can be given at the present time. It should be emphasized that this is not a final estimate, and a detailed investigation might serve to reduce or increase the amount submitted.

The cost of the different reservoirs per unit capacity will depend principally upon the value of the land to be submerged. A large part of that covered by the proposed system has only nominal value. On the other hand some of it is good agricultural land while in a few locations there are coal deposits. Many of these will be worked out in a few years. Exploration of the coal region shows that by far the greater part of the coal lies above the proposed flow lines.

We will use as a standard of comparative costs 97 artificial storage reservoirs of various sizes that have been erected in America, Europe, India and other places or which have been projected for erection with costs carefully estimated. Such a comparsion is of course, merely relative and too great weight should not be given to it, yet, inasmuch as a wide variety of conditions is covered by these reservoirs and the costs thereof vary according to such conditions, it may be expected that the reservoirs contemplated in this paper will approximate in some degree those costs and the estimate will have the advantage of being based on work actually achieved or which has had the minute study of competent engineers.

It has been found from an examination of these figures and, indeed, it is a matter of common observation among engineers, that the greater the capacity of any reservoir, the smaller the cost per unit capacity. Classifying these capacities and determining the cost per cubic foot per second per year we have the following statement:

Capacity in Millions of cu. ft.	Cost per Second-Foot per Year	Number of Reservoirs.
Less than 10	$118,666	3
10 to 50	112,800	5
50 to 100	79,417	10
100 to 500	36,495	21
500 to 1,000	20,775	12
1,000 to 10,000	7,047	35
10,000 to 20,000	1,664	8
Over 20,000	1,210	3

Examination of the various items making up each class in the above table shows that they are fairly uniform and, save for an exceptional entry here and there, there are not unusually wide departures. The averages in each class are justly representative of the class.

We will now consider the cost of the reservoirs specified in tables previously given. There are, in the proposed system, two reservoirs of capacity of 500 to 1,000 million cubic ft. The foregoing table shows that such reservoirs cost $20,775 per second foot yield. Multiplying the yield of each of the two reservoirs above noted by $20,775, the result is $1,050,000. Following the same process throughout the entire system, we secure the following statement:

ESTIMATED COST OF RESERVOIRS SHOWN IN PROPOSED SYSTEM.

Number of Reservoirs.	Capacity in Millions of Cubic Feet.	Estimated Cost.
2	500— 1,000	$1,050,000
52	1,000—10,000	53,784,000
15	10,000—20,000	12,545,000
31	Over 20,000	57,840,000
100		$125,219,000

At first glance the costs above suggested seem large, but there are two considerations which will ameliorate the severity of the first impression. The first is that the cost for such a reservoir system will be progressive. The scheme involved is not one that can or should be carried out at one fell swoop but, on the contrary, it forms the nucleus of a policy which, if adopted, could be the guide to government expenditures in future years. The government will probably expend an equivalent sum of money for some form of improvement in the Ohio basin during the next twenty years, and therefore the real question to be faced is whether the money shall be expended for permanent improvements in the shape of reservoir construction or shall be expended for canalization and for temporary expedients, such as dredging. After all, it comes down to a question of which is the best way to expend a given sum of money.

The second feature to be taken into consideration is that the value of any project is not determined by the amount of money used in its construction, but by the final utility of the project. If the value of the proposed system be placed alongside the total cost for construction, assuming the above estimate to be fairly representative, it will be seen that the scheme may be cited as an excellent investment. Some of the values resulting from the construction of the proposed reservoir system have been cited in previous pages. They may be classed as follows.

(1) BENEFITS TO NAVIGATION.—The reservoir system will make the construction of many of the proposed dams along the Ohio unnecessary. These dams will cost over $1,000,000 each. The effective cost of the reservoir system will therefore be reduced by an amount equivalent to the cost of the locks and dams that it would be necessary to construct in the Ohio if said reservoir system were not installed. Again, navigation on all the conserved tributaries will be improved, and many costly proposed improvements on said tributaries will be rendered unnecessary. Tennessee River, for example, between Riverton and the mouth would be converted into a great navigable highway, with a guaranteed 9-ft. channel. The upper sections of the river would be similarly benefited. The cost of proposed improvements in these tributaries, made unnecessary by the reservoir system, should be credited to said system, thereby reducing its effective cost. Because the author is not in possession of the late report concerning canalization of the Ohio, he is unable to venture an opinion concerning the amount of money which should be credited to the reservoir system by reason of the above considerations.

(2) BENEFITS ARISING FROM FLOOD PREVENTION.—This is a vast item—no definite estimates can be made. An estimate of the damage caused by the January and March floods of 1907, compiled from local reports along the valley, amounted to more than $100,000,000. This estimate included destruction of real and personal property and interruption of trade, but did not include depreciation. This is the most serious of all flood losses. Trade can be recovered, buildings can be restored and commodities can be replaced, but the depreciation of real property or the stalling of its development by reason of flood menace is a factor that will persist as long as floods are imminent. The ultimate loss is far greater than all the other factors of flood damage. The proprietor of a great manufacturing establishment on the banks of the Ohio, in discussing with the writer the value of the deep waterways movement, stated that, so far as the real interests of his company are concerned, the desirability of the proposed 9-ft. channel is not to be compared with the need for flood relief. He said, in effect: "We can prosper without the water transportation, but we cannot withstand the flood losses. If floods persist we must move."

(3) WATER POWER.—If any method can be devised by which the United States Government can realize a fair return on the additional water power created by the proposed storage system, the entire cost of the reservoirs would be returned to the treasury. Charges for water power need be maintained only until the cost of the system of reservoirs has been repaid, after which, if it be determined wise, the water rights can be turned over to the water users, after the manner prescribed in the Reclamation Act of 1902. Let us consider some of the possibilities of power production:

The total fall in the Ohio at Louisville is said to be about 27 ft. A large part of this fall is obliterated during flood seasons, especially when such floods involve the Wabash, Cumberland and Tennessee rivers, as well as some of the tributaries entering the Ohio above Louisville. It has been estimated that if the tributary basins were conserved up to their maximum, the fall at Louisville would be at least 22 ft. For purposes of safety we will consider only 18 ft. available. Now, the capacity of the reservoirs proposed in this paper, on the Ohio tributaries above Louisville, is such as to provide for a flow at Louisville during six months of the year of 67,000 cu. ft. per second. The unconserved drainage area above Louisville may safely be expected to provide at least an equivalent amount during the remaining six months of the year. Considering then an assured flow of 67,000 cu. ft. per second at Louisville and an 18-ft. fall, there is indicated an available horsepower of about 110,000. This figure involves only 80% efficiency on power wheels. This amount, figured at $20 per HP.-year, is equivalent to 3% income on $73,000,000.

The value of power on the Monongahela dams has already been cited, as well as that on the proposed Youghiogheny dams. An estimate is also given on a previous page of the value of total indicated horsepower made available by the proposed reservoir system in the Great Kanawha basin. Assuming only one-half of this to be available for economic development, there would result the equivalent of a 3% income on $155,000,000.

The Allegheny, the Cumberland, and especially the Tennessee, might be cited further, but, inasmuch as this is not a water-power report, the purpose of this section, viz., to show the possibilities of good returns on the proposed investment, will be amply served by the examples given.

In closing, the author begs leave to state that the determination of the enormous water supply possibilities in the Ohio basin, discussed in previous pages, constitutes a part of the work of the U. S. Geological Survey.

THE CHICAGO SUBWAY SYSTEM FOR STREET cars is being given serious consideration by the city officials, and Mayor Busse has sent to the council a message urging that steps be taken towards planning a definite project. It is generally assumed that the system will be for the use of street cars only, in order to avoid the present congestion in the business districts, but it has also been proposed to include the elevated railway trains (having in view the ultimate removal of the elevated loop). The subway will undoubtedly be made as shallow as possible. They will interfere seriously with the complicated network of water mains, sewers, electrical conduits, gas mains, and other underground facilities. In view of this fact, and of the inadequacy of the present sewer system of the business district, together with the proposition for a high pressure water main system for fire protection, the mayor has advised that the subway plans should include galleries for the accommodation and proper arrangement of the various underground facilities. Various plans have been proposed and some have been submitted to the local authorities. Two comprehensive projects were worked out some time ago by Mr. Bion J. Arnold, M. Am. Soc. C. E., M. Am. Inst. E. E., and Mr. George W. Jackson (Engineering News, July 19, 1906, and Dec. 22, 1906). The project is as yet only in the formative stage and the financial problem is a very serious matter.

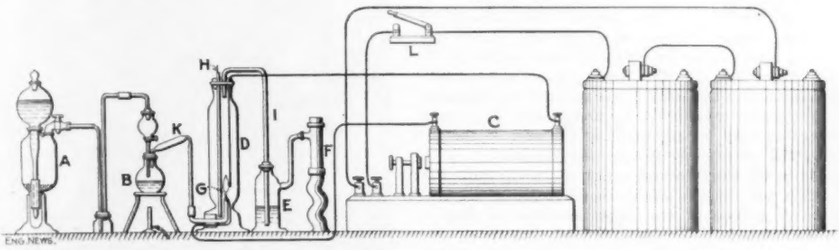
THE DETERMINATION OF SULPHUR IN PIG IRON AND STEEL BY THE HYDROGEN JET METHOD.

By RANDOLPH BOLLING,* M. Am. Chem. Soc.

Sulphur is now almost universally determined in iron and steel works laboratories by the "evolution method," so called. It is a rapid method and, for most work, has stood the test of time. The operating details are few and simple; the samples of steel or pig iron drillings are acted on by dilute hydrochloric acid in a suitable evolution apparatus and the mixture of hydrogen, hydrocarbons, mercaptan (complex organic sulphides) and sulphuretted hydrogen gases, generated by the action of the acid on the metal drillings, are conducted into an absorbing solution, of which there are several to choose from—plain alkaline solutions like caustic soda or potash or alkaline metallic-salt solutions such as cadmium chloride and ammonia or zinc chloride and ammonia. All these have certain good points in their use, although the writer prefers the cadmium solution. The final stage is to acidify the absorbing solution with hydrochloric acid and titrate the liberated sulphuretted hydrogen with a standard iodine solution standardized to show milligrams of sulphur per c.c. of solution or percentage of sulphur in the steel.

Some years ago it was pointed out by different observers that with certain brands of pig iron the evolution method failed to act quantitative with the result that the analyses made were lower in sulphur than were the figures obtained by the old gravimetric methods depending on other chemical reactions. Investigations made at the time showed very clearly that the absorbing solutions used with the volumetric method allowed some of the sulphur in the form of mercaptan or complex organic sulphides to bubble through them without combining with the absorbent. In order to overcome this defect, oxidation of the sulphur gases by bromine or by passing them through red-hot platinum tubes was proposed by different chemists. Both methods oxidize completely and give accurate results. However, the main difficulties in the use of a bromine absorbent are that the final stage is gravimetric and very slow, and that no chemist can stand working in a bromine atmosphere for any length of time. The red-hot platinum tube was excellent from a research laboratory standpoint, but at present for a works laboratory is rather an expensive luxury; besides, the idea of working over a 20-burner combustion furnace is not pleasant in August.

The following method, worked out by the writer, is particularly applicable to those brands of pig iron that do not give satisfactory results with the ordinary evolution method. It is carried out in a special arrangement of apparatus, shown in the accompanying figure.



ARRANGEMENT OF APPARATUS FOR THE HYDROGEN JET METHOD OF DETERMINING SULPHUR IN IRON AND STEEL.

The apparatus consists of a Kipps generator, A, filled with chemically pure zinc and dilute hydrochloric acid and connected with the half liter flask, B, which is closed by a rubber stopper carrying a stop-cock funnel (not shown) and an inlet tube from A and the outlet tube K. D is a 16-in. calcium-chloride tower. The tube, K, terminates in a jet as G. H is a ½-in. tube which serves as a draft tube furnishing air to supply the jet, G. The tower is closed at the top by a No. 8 rubber stopper which carries the draft tube and the outlet tube, I, and is also perforated by two iron wires terminating in a ¼-in. spark gap over the jet tube, G. The wires are run to the secondary of the Ruhmkorff coil, C, whose primary circuit is so connected with three cells of Edison-Lalande battery that it may be opened or closed by the switch, L. The tube, I, leads to the Silliman gas bottle, E, filled with a 5% solution of sodium carbonate containing a few drops of potassium permanganate, and is connected by tubing to the Chapman aspirator pump, F.

To make a determination with the apparatus, five grams of pig-iron or steel drillings are transferred to the flask B, the stopper is closed, the stop-cock on the Kipps generator is opened and the entire system filled with pure hydrogen, having disconnected the tube at M. After the flask and tubing have the air originally in them replaced by hydrogen, connect the bulb M with the tower and close the primary circuit of the Ruhmkorff coil. The funnel tube of the flask B is filled with 100 c. c. of hydrochloric acid (1.10 specific gravity) and this is run in on the sample. The bunsen burner is lighted and the heat regulated so as to avoid too vigorous an evolution of gas as the acid reaches a boiling temperature. The hydrogen should be gradually admitted towards the end of the reaction to sweep out the last of the gases evolved from the metal under test. The terminals for the ignition-spark gap may be changed by fusing a small platinum tube in the glass jet G and connecting with one terminal of the coil. The other terminal of the coil remains connected to an iron wire, and the sparks now jump between the platinum tip and the wire. A little practice with the apparatus will enable one to get the aspirator and the hydrogen generator adjusted so as to get a steady jet of burning gas in the tower. After a run is completed, the solution of sodium carbonate containing all of the sulphur is transferred to a beaker, acidified with hydrochloric acid and heated to boiling. The sulphur present in the iron under test is in the form of FeS_2, MnS, and by reacting with the hydrochloric acid is evolved as H_2S. This is in turn oxidized in the hydrogen flame to SO_2, which reacts on the Na_2CO_3 to form $Na_2SO_3 + CO_2$. The sodium carbonate solution is of such a low degree of concentration that the sodium sulphite formed remains in solution. By slightly acidifying with hydrochloric acid the sulphite is decomposed as follows:

$$Na_2SO_3 + 2\ HCl = 2\ NaCl + H_2O + SO_2.$$

Owing to the reaction taking place in a comparatively large volume of cold water, there is no evolution of SO_2. 10 c. c. of potassium permanganate solution saturated, is now added to oxydize the SO_2 to SO_3 and hot solution of 10% barium chloride is now added, using about 10 c. c., the solution is boiled 30 minutes to precipitate all of the barium sulphate, allowed to stand until just warm and then filtered either through paper or preferably through a platinum Gooch crucible with an asbestos felt, ignited and weighed and the percentage of sulphur calculated.

$$\text{Weight } BaSO_4 \times 0.1375 \times 100 \over 5 = S \text{ in per cent. of sample of iron.}$$

The factor 0.1375 enters the equation by representing the milligrams of sulphur in one gram of barium sulphate. The SO_3 in solution, of course, reacts on the barium chloride, forming barium sulphate and the percentage of sulphur determined.

The results obtained are thus gravimetric. If it is desired to read the results of the determination by a volumetric process, a slight change in the procedure is necessary. Potassium permanganate is not added to the sodium carbonate solution used in absorbing the sulphur dioxide formed by oxidation of the gases evolved in the burning hydrogen, but the strength of this absorbing solution is increased to 8%. After a run with the hydrogen jet apparatus exactly as for a gravimetric determination, the absorbing solution is now transferred from the Silliman gas-washing bottle to a wide mouth one-liter Erlenmyer flask; a bit of litmus paper is dropped in and strong hydrochloric is added until acidity is shown by the litmus paper turning red. The flask, containing the sulphur as sodium bisulphate, is now brought under the stop-cock of a refilling burette (a burette that can be filled automatically from an overhead stock bottle) containing a standard solution of iodine, and is rapidly titrated, using starch indicator. The number of cubic centimeters of iodine required to react to a blue color multiplied by the value of the iodine solution in sulphur equivalent gives the weight of sulphur found. This result divided by 5 and multiplied by 100 gives the percentage of sulphur in the iron or steel sample operated on. By working the method by the volumetric process the amount of time and manipulation expended to obtain a result is very materially reduced. The aim in using iodine as an indirect oxidizing agent lies in its action on the elements of water forming hydriodic acid and liberating oxygen in an active state. This action can be applied to the determination of the sulphur in the SO_2, which, it will be recalled, was left in the absorption vessel "E." The reaction in this case is:

$$SO_2 + I_2 + 2\ H_2O = 2\ HI + H_2SO_4.$$

The iodine gives a blue reaction with the starch only when hydriodic acid ceases to be formed and free iodine results from the addition of the titrating solution. This happens when all the SO_2 is oxidized to H_2SO_4.

The standard titrating solution of iodine may be conveniently prepared after the following method of procedure: 17.5 grams of potassium iodide is dissolved so as to form a saturated solution. (The writer recommends that not over 250 c. c. water be used.) Then 7.9140 grams of iodine is weighed on balanced watch glasses and dissolved in the solution of potassium iodide. It has been found in practice that iodine dissolves more readily in a saturated than in a dilute solution of this salt; 17.5 grams of the salt is just sufficient to cause the solution of this weight of iodine. After the solution of the solid iodine has been accomplished, it should be made up to exactly four liters with distilled water. By using this particular weight of iodine the calculation of the results is much simplified. One c. c. of this standard solution, if chemically pure iodine has been used, is theoretically equivalent to 0.00025 gram of sulphur, or 0.005% in a 5-gram sample of iron tested. This value would not need to be checked if absolute reliance could be placed on the C. P. label on bottles of chemicals. As that is not the usual case, the solution should be carefully standardized. For such calibration there are several quantitative reactions to choose from, but as arsenious oxide is made by sublimation, it is usually found strictly C. P., and is to be preferred. The reaction employed in the writer's method is:

$$As_2O_3 + 2\ I + Na_2CO_3 = As_2O_5 + NaI + CO_2$$

By this reaction 1 gram of iodine in solution is equivalent to .495 gram arsenious acid. The standard solution (4,000 c. c.) as made up contains 7.9140 grams of iodine so that 1 c. c. should be equivalent to .000983 gram arsenious acid.

For convenience in standardizing the solution

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of iodine, a weight of .0309 gram of arsenious acid (or a multiple of that weight) is taken, as computation shows this figure has the same chemical equivalent as 0.01 gram of sulphur, provided this chain of reactions outlined is followed. The actual procedure for standardizing the titrating solution is as follows: Weigh three portions of 0.0309 gram, 0.0618 gram and 0.0927 gram of arsenious acid C. P. into three small No. 2 Griffin's beakers and cover with about 10 c. c. of hot water. Close the beakers over with watch glasses and heat slowly on an electric hot plate so that the water just boils. Remove from plate and add 0.6, 1.20 and 1.80 grams of pure dry sodium carbonate to each beaker, the .0309 gram of acid taking 0.6 gram of soda and the 0.0618 gram of acid taking 1.20 gram, and so on. The beakers are now replaced on the heater and boiled until every particle of arsenious acid has been dissolved. This usually requires about five minutes' boiling. The beakers are now removed from the heater, cooled and diluted half full with cold water. They are now titrated with the iodine solution, adding a few drops of a starch solution to each beaker. It is best to observe closely when the iodine begins to fade out slowly, and then add the starch. A good sharp end reaction results with a fine blue color the instant the end point of the reaction is reached. The standardization is run in triplicate to secure good checks on results. As an example of actual results of the standardizing, suppose the beaker containing 0.0309 gram of arsenious acid required 45.6 c. c. of the iodine solution to produce the blue reaction. As 0.0309 gram of the arsenious acid is equivalent to 0.0100 gram sulphur, under the conditions kept,

$$\frac{.01}{45.6} = .000219$$

and 1 c. c. solution represents .000219 gram sulphur. This amount of sulphur is .00447% of the 5-gram sample of iron, and each c. c. of the standard iodine solution used in determining the sulphur content of the Erlemyer flask represents that .00447% of the original sample was sulphur.

RESULTS OF ANALYSES.—In order to check the results obtained by this new method with some results obtained by the older ones now employed at blast furnaces and steel works, three determinations were made on each sample operating with the hydrogen jet and the iodine titration, these results are marked A in the accompanying table. The sulphur was then determined in the sample, using the usual evolution method with a solution of cadmium chloride made alkaline with ammonia water; these results are marked B. A third series using the evolution method with caustic soda solution are marked C. These results are compared in the accompanying table.

COMPARISON OF RESULTS OF DIFFERENT METHODS OF DETERMINING SULPHUR IN IRON.*

Cast No.	Metal.	Per cent. of Sulphur found.	Method
741	Basic Pig Iron	.0093	A
741	" " "	.0084	B
741	" " "	.0081	C
896	" " "	.029	A
896	" " "	.020	B
896	" " "	.019	C
1004	No. 1 Foundry Iron	.0250	A
1004	" " "	.0194	B
1004	" " "	.0190	C
1064	Grey Forge Iron	.099	A
1064	" " "	.085	B
1064	" " "	.081	C
108	White Iron	.238	A
108	" "	.217	B
108	" "	.210	C
Heat No.			
1246	.30 Carbon Steel (O.H.)	.044	A
1246	.30 " " "	.040	B
1246	.30 " " "	.041	C
2401	.55 " " "	.026	A
2401	.55 " " "	.020	B
2401	.55 " " "	.019	C
3090	.08 " " "	.050	A
3090	.08 " " "	.049	B
3090	.08 " " "	.046	C

*The oxidation is so perfect in the hot hydrogen flame that no sulphur compounds escape complete oxidation; this accounts for the higher results obtained. In absorbing without using special means some sulphur must escape.

The novelty in the method outlined lies chiefly in the oxidation of the sulphur by the hydrogen jet and in the practical details, such as the combustion chamber, the ignition spark apparatus, the oxygen supply tube, etc. The method works best only under good laboratory conditions and in the hands of competent persons rather than amateurs.

A HIGH-SPEED OIL-ENGINE AIR COMPRESSOR: FEATURES OF DESIGN AND RESULTS OF TESTS.*

The well-known Mietz & Weiss oil engine has recently been applied to driving a direct-connected air compressor. The makers have taken a line of three-cylinder vertical oil engines and have replaced one cylinder with an air-compressing cylinder. In the smaller sizes a single power cylinder may be used. For low pressures and large volumes two air cylinders can be used in multiple. These units are being built in capacities of 10 to 250 cu. ft. of free air per minute compressed to a pressure of 10 to 100 lbs. per sq. in. Fig. 2 shows one of these units as built with a single air-compressor cylinder.

THE OIL ENGINE.—The engine which is designed and built as an integral part of the compressor outfit is a two-cycle, two-cylinder vertical type, having the general features of the Mietz & Weiss horizontal single-cylinder oil engine, described with results of tests in Engineering News of Sept. 15, 1904.

The action of the engine is best seen by reference to Fig. 2, which shows the complete engine-compressor unit.

The fuel oil is stored in a tank which may be placed beside the engine or underground if necessary. The oil is fed into the cylinders through nozzles by a pump. Each nozzle has a needle valve for putting one cylinder out of action if desired. The ignitor is a hollow spherical-shaped casting, which, before starting the engine, is heated by a gas or oil torch whose position is indicated on Fig. 2. The ignitor carries a projection against which the oil is sprayed by the nozzle. As this projection is necessarily at nearly the same high temperature as the rest of the ignitor the oil is immediately vaporized.

Air is drawn into the crank case, through the suction port by the upward movement of the piston. A glance at the cross sections of Fig. 2 shows that, at the completion of the up stroke, the volume of air in the crank case really includes the amount held in the lower part of the cylinder and in the whole interior of the elongated piston. On the down stroke the suction port is closed and the air thus locked must be compressed until the inlet port is cleared near the end of the stroke. At the same time the exhaust port is overrun and the products of combustion are discharged. The semi-annular lip seen on the top of the piston serves to deflect the entering air so that it does not by-pass across the top of the piston and out the exhaust but rather helps to clear the cylinder of spent gases.

The water jacket around the cylinder has no circulating system so that steam is generated by the heat absorbed. The steam is led through passages (S) to the air passages leading to the inlet so that with the compressed air there is admitted a certain amount of water vapor which naturally increases with increased load and greater absorption of heat by the jacket water. The admission of steam in this way has been found advantageous in reducing trouble from soot in the chamber to such an extent that common American kerosene and even crude oil can be used. By a float-operated valve, somewhat like a steam trap, the water in the jacket is maintained at a constant level whatever the temperature or rate of evaporation.

The engine is governed by regulating the fuel supply. The plunger of the fuel pump is operated by an eccentric controlled by a centrifugal governor, which is, in turn, driven through gears and a silent chain from the main shaft. The speed of the engine can be increased or diminished by increasing or diminishing the tension on the governor springs. A hand regulator is also provided to limit the stroke of the pump or to disconnect the driving eccentric, thereby stopping the engine.

HIGH-SPEED AIR COMPRESSORS.—The common scheme for driving air compressors by oil or gas engines, of the sizes discussed in this article, has been with belts or gears. The direct-connected arrangement shown in Fig. 2 has many advantages in compactness, reduced floor space and in simplification of apparatus. The results of tests, to be disclosed later in this article, have shown its operation to be efficient and satisfactory at 400 r. p. m. and one type has been developed for use at 600 r. p. m.

Advantage is taken of the preliminary compression that may be obtained in the crank case just as with the engine. Air is admitted through an inlet, similar to those on the power-end on the up stroke of the engine. On the down stroke this port is closed and the air thus confined is compressed. At the same time the cylinder above the piston is filled with air at atmospheric pressure through the mechanically operated suction valve. This valve is closed as the equalizing port is overrun by the piston head and the compressed air of the crank case rushes into the cylinder. The resultant initial pressure

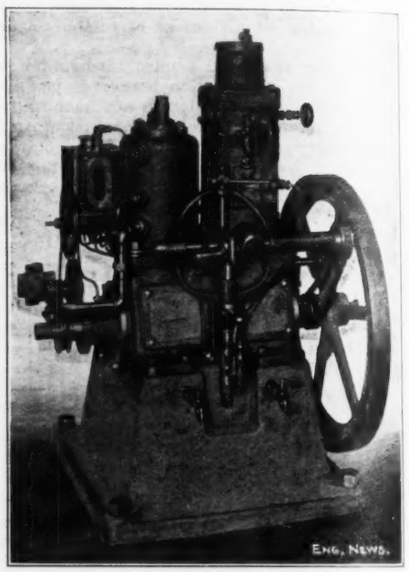


Fig. 1. Small Air Compressor of The Mietz & Weiss Oil-Engine Type.

of the air in the cylinder at the beginning of the compression stroke is thus a few pounds above atmospheric.

METHODS AND RESULTS OF TESTS.—Fig. 3 shows the characteristics of two indicator cards on the compressor. The light-spring card was taken to show the functions of the equalizing port. At high speeds the pencil mechanism is subject to considerable vibration, which affects the indicator card. A fair card could be obtained only with a short movement of the drum and a heavy spring.

The real commercial value of any compressor depends, aside from the question of maintenance and investment, on the quantity of air delivered and the power required for the duty imposed. Of three compressors of the same type, size, clearance volume and speed, one may discharge what may be considered a normal quantity of air, against a normal pressure, and by the "consumption" of a normal amount of power; the second machine may discharge less air at less power input, owing to leakage; the third may discharge still less air at a greater power input due to throttling and heating.

It is common to specify the piston displacement per minute as the quantity of air delivered. One refinement of this plan is obtained by multiplying the displacement by a "volumetric efficiency" factor which is the ration $\frac{bc}{ac}$ from

*From information and data furnished by Mr. A. Peter, M. E., with August Mietz, 128-138 Mott St., New York City.

the card, Fig. 4. The length of the line a-b depends on the clearance volume and the nature of the re-expansion curve e-b. The theoretical factor obtained from the card is always more or less higher than the true value, a condition which may be caused by the heating of the entering air due to the higher temperature of the cylinder walls and piston and by leakage past the piston indicator cards is too unreliable and unsatisfactory. It became advisable in testing this air-compressor to determine the discharge by direct experiment.

The method of obtaining the volumetric efficiency here employed consisted essentially of pumping up a tank of known dimensions from one pressure to another and observing the time

$$Q = v(273 + t_3)\left(\frac{29.92}{B}\right)\left(\frac{\frac{p_2}{273 + t_2} - \frac{p_1}{273 + t_1}}{14.7}\right) \quad \text{(b)}$$

where

t_3 = Suction temperature.

B = Barometer reading in inches of mercury.

This expression now gives cubic feet of air at suction temperature.

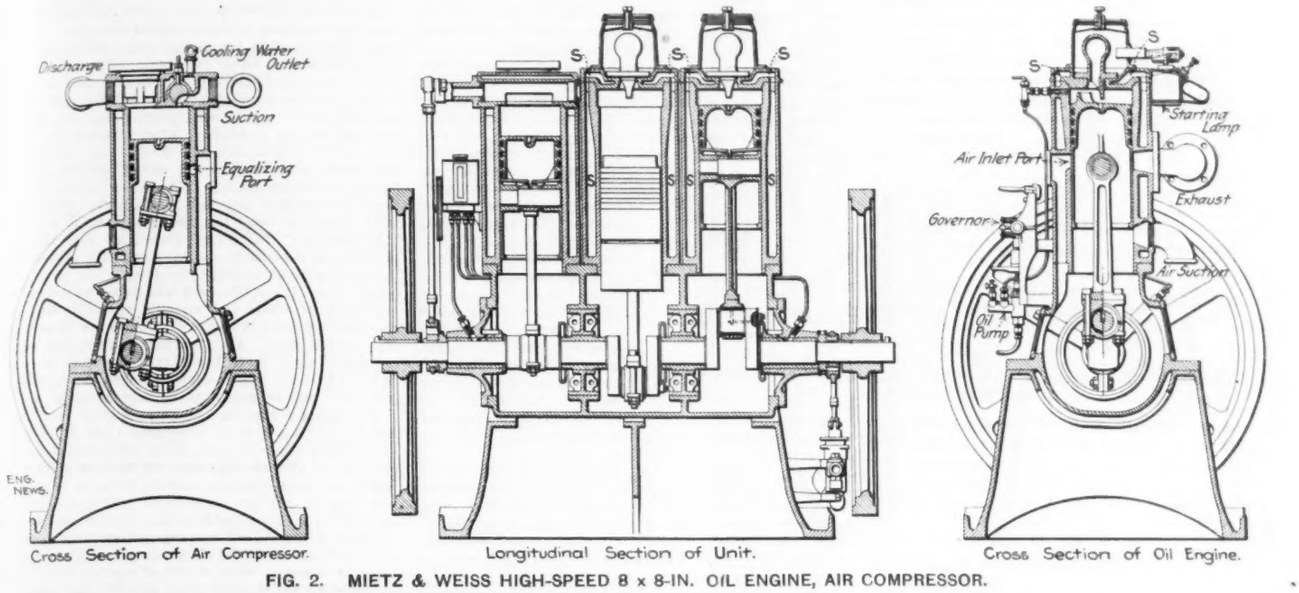


FIG. 2. MIETZ & WEISS HIGH-SPEED 8 x 8-IN. OIL ENGINE, AIR COMPRESSOR.

and into the suction pipe. Moreover, a compressor with a mechanically operated suction valve can be adjusted so that any apparent volumetric-efficiency factor desired can be obtained from the indicator card. It is only necessary to open the suction valve as the piston starts the back stroke so that the compressed air left in the clearance space passes into the suction pipe. Then the re-expansion curve e—b (Fig. 4) falls very rapidly, and while then the ratio $\frac{b\,c}{a\,c}$ is high there is an unrecorded loss of air and of power. A mechanically operated suction valve should not open before the re-expansion curve cuts the atmospheric

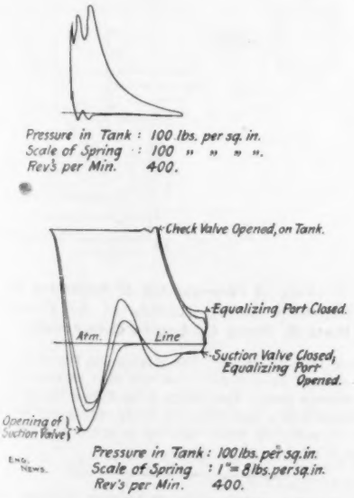

Pressure in Tank : 100 lbs. per sq. in.
Scale of Spring : 100 " " " ".
Rev's per Min. 400.
Check Valve Opened, on Tank.
Equalizing Port Closed.
Atm. Line
Suction Valve Closed, Equalizing Port Opened.
Opening of Suction Valve
ENG. NEWS.
Pressure in Tank : 100 lbs. per sq. in.
Scale of Spring : 1" = 8 lbs. per sq. in.
Rev's per Min. 400.

Fig. 3. Indicator Cards; Air Cylinder of Oil-Engine Compressor.
(One-half scale.)

line. However, this point is difficultly determined and, indeed, actually changes with a change in discharge pressure.

It is thus seen that if an accurate determination of the air discharged from a condenser, of the type tested, is desired a method dependent on

General Dimensions:

Air Compressor;	Diameter cylinder, 8 ins.; Stroke of piston, 8 ins.; Cu. ft. per min., 100; Lbs. per sq. in., 100.
Oil Engine;	Diameter cylinders, 8 ins.; Stroke of piston, 8 ins.; HP., 24; R. P. M., 400.

and number of revolutions required. As a corollary of Boyle's law we have:

$$Q = v\left(\frac{p_2 - p_1}{14.7}\right) \quad \text{.....(a)}$$

where

Q = cu. ft. of air pumped from the atmosphere into the tank.

p_1 = initial absolute tank pressure, lbs. per sq. in.

p_2 = final absolute tank pressure, lbs. per sq. in.

The volumetric-efficiency factor is then Q divided by the piston displacement for the observed length of time or number of strokes. It should be noted, however, that if the tank is merely pumped up from atmospheric to the full rating pressure of the compressor then the volumetric-efficiency factor will be too large for the maximum pressure obtained.

The figure obtained will be one for a certain average of all the pressures discharged against. The cause of this is seen from Fig. 5, where the re-expansion curve changes for different discharges, so that the part of the card corresponding to a-b in Fig. 4 will increase with increasing pressure and true volumetric efficiency will decrease.

With the arrangement used in these tests, shown in plan Fig. 6, this trouble is avoided. Two tanks, E and F, were used, and by means of the regulating valve V the air in F was maintained at that constant pressure for which the volumetric efficiency was to be determined. The large tank E was pumped up from one pressure to another, each one lower than the pressure in F, to determine the amount of air pumped.

If the compressor is close to the tank E the temperature of the air in the latter is considerably higher than when drawn into the compressor, unless the cooler, shown in Fig. 6, is used. In any case proper temperature corrections should be added to the expression (a) for suction, initial tank and final tank temperatures. A barometric correction also should be inserted. The expression (a) thus modified reads:

The principal data of the volumetric-efficiency tests are shown in Table I and Fig. 7.

Each test was made at least three times, and the values given in Table I are an average. The data from each separate test do not vary more than 1.25% above or below the average.

Three groups of volumetric efficiency tests were made: (A) Taking advantage of the pressure in the crank case and running at about 100 r. p. m. (B) Taking no advantage of the pressure in the crank case and running at about 400 r. p. m. (C) Taking advantage of the pressure in the crank case and running at 240 r.p.m. The results of (B) and (C) are not tabulated, as they are similar to Table I and are shown in Fig. 7. The curve C shows that any slight leakage by the piston or valves is of greater consequence with a slow speed compressor. A method commonly applied to determine leakage is by closing the suction pipe and attaching a suction gage. In this test this was done and 98.5% of perfect vacuum was indicated at full rated speed. This is close to the lowest possible at 1¼% clearance in cylinder.

In Fig. 7, B, curves are plotted for comparison showing the theoretical volumetric efficiency de-

TABLE I.—VOLUMETRIC EFFICIENCY TESTS OF A MIETZ & WEISS COMPRESSOR.

Number of Run.	1	2	3	4	5
Barometer Reading, ins. mercury	29.9	29.9	29.9	29.9	29.9
Equivalent Atmospheric, lbs. per sq. in.	14.7	14.7	14.7	14.7	14.7
Pressures:					
Compressor Discharge, lbs. per sq. in.	44.1	58.8	73.5	88.2	103
Tank E, Initial (p_1)	14.7	14.7	14.7	14.7	14.7
Tank E, Final (p_2)	44.1	58.8	58.8	73.5	88.2
Temperatures:					
Tank E, Initial (t_1) C.	30.5°	30.5°	32°	32°	33°
Tank E, Final (t_2) C.	37°	42.5°	43.5°	46.5°	50°
Suction (t_3) C.	30.5°	30.5°	30.5°	30.5°	30.5°
Cooling Water, Inlet C.	13°	13°	13°	13°	13°
Cooling Water, Outlet C.	27°	29°	30°	31.5°	34°
Cooling water, Appx. Gals. per hr.	90	90	90	90	90
Duration Run, Sec.	63.6	97.6	99	132.4	171
Total Revolutions	444	678	680	900	1,161
R. p. m.	419	417	412	408	406
Actual cu. ft. Air discharged per Min.	103.3	99	97.4	96	92.6
Piston displacement per Min.	97.5	97	95.9	94.9	94.5
Volumetric Eff'y Factor, %.	106	102	101.5	101	98

Compressor data:

Diam. Cylinder	8 ins.
Area Piston	50.26 sq. ins.
Length Stroke	8 ins.
Piston Displacement	23.27 cu. ft.
Clearance Volume	1.25%
Contents Tanks, Including Piping	87.2 cu. ft.

sired from isothermal and adiabatic re-expansion of the air in the clearances.

Valves of the power required to operate the compressor were determined by the following method. The connecting rod of the compressor piston was disconnected from the crank shaft and the oil engine was tested for B.HP. and oil consumption. The results of this test are shown by Table II and Fig. 8. After this test the compressor end was connected up again and the machine started. By manipulating the regulating valve V, shown in Fig. 5, it was possible to deliver air freely with constant pressures at the tank, F, at the designed speed of the compressor. The oil consumption was recorded and the B.HP. developed taken from Fig 8. These data are given by Table II and are plotted on Fig. 9.

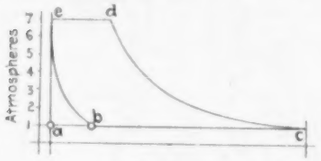


Fig. 4.

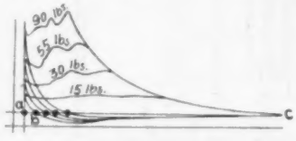


Fig. 5.

FIGS. 4 AND 5. THEORETICAL INDICATOR CARDS; AIR CYLINDER OF COMPRESSOR.

The theoretical HP. required for adiabatic compression is also shown there for comparison. This curve is derived from a theoretical indicator card neglecting clearances or from various thermodynamic expressions as contained in Kent's Pocket Book, p. 501.

The cost of a 10-hr. run of this type of compressor delivering 100 cu. ft. of free air per min. is as follows:

Fuel oil at 4½ cts per gal.	$1.50
Water	.10
Lubricating oil, etc.	.50
Proportionate charge for attendant	.50
	$2.60

This is, of course, based on the supposition that the attendant will have other work besides watching this compressor.

OPERATIONS OF THE WATER SOFTENING PLANT AT OBERLIN, OHIO.

The water softening plant at Oberlin, O., which we understand is the first permanent municipal plant for the purpose put in operation in the United States, was described and illustrated in Engineering News of Sept. 21, 1905. The last annual report (1907) of Mr. W. B. Gerrish, Engineer and Superintendent of the Oberlin Water-Works, contains some interesting notes on the operation of the plant.

The softening works were put in operation about four years ago. Mr. Gerrish states that although at first there was bitter opposition and stories of all sorts of "tastes, smells and ill effects" in and from the water, the plant is now regarded with general favor.

A number of paragraphs from the report are of sufficient interest to warrant reprinting, as follows:

It was always considered one of the first principles of water softening that every particle of raw water should have its proportionate amount of chemicals mixed with it; and we took great pains to attain that end. The treated water under this method always contained at least 17 parts per 1,000,000 of residual caustic alkalinity and we supposed that that could not be avoided. We discovered, however, that if the chemicals for a day's run were introduced into one-half the raw water and the balance let into the basin without chemicals the caustic alkalinity disappeared. This was true until the colder weather came and the temperature of the raw water went below 13° C. when the caustic alkalinity again appeared. We then began to add a small amount of sulphate of iron to the water as it flowed from the first basin to the second. The amount of iron was gradually increased until when the water reached its maximum density we were using 2 grains of iron per gal. The iron sulphate removes all the caustic alkalinity and the water is as nice as in summer.

At first the amount of chemicals was determined empirically but for a year we have analyzed the raw water for alkalinity, incrustants, magnesium and free carbon dioxide, according to the methods recommended by the Laboratory Section of the American Public Health Association and then calculated the chemicals to add. By this method much better and more uniform results have been obtained.

During the first part of the year we used a lump lime containing 89% CaO and the rest of the year an hydrated lime put up by the same firm containing 69% CaO. Our lime bill could be reduced 25% by buying lump lime in bulk. As it is the lime used during the year cost $521 and the soda $395, making the cost per 1,000 gals. of water treated 1.3 cts.

It is of interest to note that during the whole summer the raw water was alkaline to phenolphthalein, sometimes to the extent of 9 parts per 1,000,000. This, however, did not interfere with the softening process.

During the year, records have been kept of the temperature of the raw water and also of the water in the pipe system, with the following results in centigrade readings: The raw water was at its maximum density (4) or below with the water in the system 6 until the middle of March. By the middle of May all the water was 13. The maximum temperature of 27½ for raw water was reached on June 25 and again on July 25, with the water in the mains 21 and 22. The temperature was above 20 until the last of September and reached 13 the middle of October. The maximum density was again reached the last of November.

The amount of lime used during the year has varied from 3.4 to 9.4 grains per gal.; while the soda ash varied from 1.2 to 3.1 grains per gal.

Chara has grown in the reservoir ever since it was built and at certain seasons of the year has given an offensive taste to the water. But little attention was paid to it until we began treating the water when the taste was attributed to the treatment. Various attempts were made to kill the chara with copper sulphate without success. The Board finally decided to put in a float intake, as the surface water seemed to be always free from the taste. In the spring of 1906 the storage reservoir was drawn down about 6 ft. and a new intake laid, provision being made for taking off the float in winter and allowing the intake pipe to rest on a support about 2 ft. below the surface. All the chara exposed by the lowering of the water was carefully raked up and carted away.

The following summer was dry and the reservoir was not filled until winter so that the area where most of the chara grew was exposed to the sun for the whole summer. In 1907 the growth of the chara was more luxuriant than ever before, but in spite of this fact there was no time during the year when the ordinary person could detect any taste. An expert visiting the plant in the summer said that he could detect a slight taste.

This fall the float was not removed when the first thin ice had formed. One day we discovered that the basins were not filling as rapidly as they should and that the water was overcharged with chemicals. Investigation showed that the festive muskrat had busied himself carrying grass to the mouth of the intake. The grass was washed along to the fish screen where it collected and almost cut off the flow of raw water. The fish screen has now been placed at the end of the intake.

In previous reports we have noted the tendency of the sand in the filters to become coated with lime. This process kept up until last spring when we found that the filters were not doing any work. Upon removing the sand it developed that the sand in the upper part of the filters was heavily coated while the lower part was cemented into a nearly solid mass. How the water got through seemed a wonder. After cleaning the strainers with hydrochloric acid the filters were renewed with lake sand having an effective size of .22 mm. and a uniformity coefficient of 1.5. This was of course a very fine sand but the idea was that as the grains became coated with lime they would increase in size and so become better with age. The filters worked all right for a few months and then the loss in head gradually increased until it was too great to make the further use of the filters practicable. When this sand was moved we found that it contained so much soft material that the attrition of washing and use had broken it down to a mud on the surface of the filter. We then put in Cape May sand as originally used. It is hoped that now that we have a water free from caustic alkalinity that the formation on the sand will be much slower than formerly.

The use of a lime-treated water without recarbonating has been regarded as an experiment from the first and a close watch has been kept on all places where the water goes, to see that coatings were not forming which in time would do harm. The pipe system seems to be free from any coating and the only place where a deposit has formed has been the inside of one make of rotary meters. Of 70 disk meters but one required cleaning on account of lime deposit. Of 270 rotary meters of one make none required cleaning, while of 390 of another make 10% required cleaning. Some of these, however, had been in use for ten years or more without touching so they needed cleaning on general principles.

There are hard deposits from the water during the process of treatment in the mixing box and the pipe leading from the same. The mixing box has to be opened and cleaned once a year and the pipe leading from the box twice a year. The sludge formed from the precipitate is turned into a near-by creek every spring and fall when there is sufficient water running to properly dilute it and carry it off.

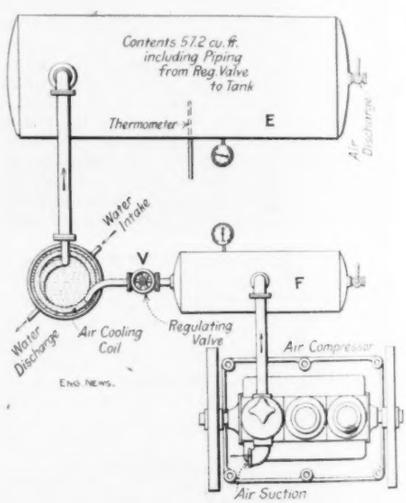


Fig 6. Plan of Arrangement of Apparatus for Determining Actual Quantity of Air Pumped by Mietz & Weiss Oil-Engine Compressor.

TABLE II.—TEST OF DRIVING END OF OIL-ENGINE COMPRESSOR SHOWN IN FIG. 1

Diam. Cylinder	8 ins.						
Area Piston	50.26 sq. ins.						
Length Stroke	8 ins.						
Piston Displacement	402 cu. ins.						
Piston Displacement from exhaust port closure to inner dead center	314 cu. ins.						
Clearance, volume	116 cu. ins.						
Clearance, % of volume at beginning of compression	27						
Number of Run.	1	2	3	4	5	6	7
B.HP.	3.9	8.0	12.16	16.55	19.2	22.42	24
R. p. m.	432	424	419	407	394	390	385
Oil Consumption, pts. per hr.	15.5	17.67	19.4	21.96	23.25	25.84	27.6
Oil Consumption, lbs. per hr.	13.7	15.62	17.16	19.4	20.55	22.84	24.48
Oil Consumption, pts. per B.HP. per hr.	3.97	2.2	1.59	1.32	1.21	1.15	1.15
Oil Consumption, lbs. per B.HP. per hr.	3.51	1.94	1.41	1.17	1.07	1.02	1.02
Cooling Water, gals. per hr.	....	....	....	....	....	10	....
Specific Gravity of Oil	0.848	0.848	0.848	0.848	0.848	0.848	0.848

TABLE III.—RESULTS OF FUEL-CONSUMPTION TEST, OIL-ENGINE, AIR-COMPRESSOR.

Tank Pressure, lbs. per sq. in. (gage)	29.4	44.1	58.8	73.5	82.2	100
R. p. m.	423	415	410	405	401	398
Cu. ft. per min., Air discharged	103.8	102.6	98.0	96.8	95	93
Total lbs. Oil per hr.	18.94	20.25	21.63	22.80	22.95	24.84
Total pints Oil per hr.	21.4	22.9	24.4	25.8	26.0	28.1
Corresponding B.HP.	15.8	18.4	20.7	22.3	22.5	24.2
Theoretical HP. adiabatic compression	8.75	11.4	13.4	14.9	16.1	17.6
Net efficiency, % (HP. adiab. comp. / B.HP.)	55.4	62.0	64.8	66.8	71.5	70.1

TUNGSTEN FILAMENT ELECTRIC LAMPS, which were described in Engineering News, July 25, 1907, as having such a fragile filament that railroad shipment caused excessive breakage, have been improved to such an extent that this loss is greatly reduced. Out of shipments aggregating 75,000 tungsten lamps the General Electric Co. reports a loss below 1.5%, and other makers report similar results. This improvement is partly due to packing each lamp in a special carton and assembling the cartons in standard packages, instead of boxing or barrelling them in straw or excelsior.

METHOD AND COSTS OF CLEANING DRIVEN WELLS AT LOWELL, MASS.*

By ROBERT J. THOMAS.†

The city of Lowell has three driven-well plants, but only one of these is in regular service, and that is known as the "Boulevard Well Plant." This plant is capable of yielding a minimum supply of 9,000,000 gals. daily. It consists of 345 2½-in. wells, ranging from 30 to 40 ft. in depth, including the strainer at the bottom, which is 36 ins. long. Every well has a valve on the pipe connecting it with the suction main and also a cap on its top, at the surface of the ground.

The first operation in cleaning a well is to close the valve and remove the cap just mentioned. A brush 3 ins. in diameter is then forced down by hand to the bottom of the strainer and drawn out again. The effect of this is to loosen the deposit on the sides of the well. The next step is to screw a No. 6 Douglas pitcher pump on the top of the well and pump the same hard for about five minutes. Then the pump handle is raised and the water in the pump is allowed to run back, which, together with water poured from pails into the well, has a still further cleansing effect. This is followed, again, by a vigorous use of the pitcher pump for a while. Thus the process of cleansing and then pumping, which we call "tripping," is continued until the water comes from the well clear. About 50 pails of water are used in this way for each well, with two men alternately pumping and tripping for about 2½ hours. The brush used is made of wire bristles; it is 3 ins. in diameter and 4 ins. long. A brush will last to clean 200 wells. The leathers on the pump, of which there are two, a clapper and a plunger leather, will last to clean 150 wells.

Usually twelve men are employed cleaning and five wells are being cleaned at a time. The gang is told off in pairs; one pair gets the well ready, removing and replacing the caps and closing and opening the valves, etc., one of these men being in charge of the work. The other ten men are cleaning and pumping. By this arrangement 15 wells are cleaned each day of eight hours. The pay of the men averages $2 per day, making the labor-cost for cleaning 15 wells $24, or $1.60 per well.

The total labor-cost for cleaning 345 wells is $652; cleaning them twice a year, as we do, of course, costs double that amount, or $1,304; add to this pump leathers, four sets, $2.20; four wire brushes, $4; five galvanized iron pails, $2.50; total for the year, $1,312.70.

A larger gang could be set cleaning and the cost per well be reduced somewhat, but shutting off too many wells at a time affects the vacuum at the pumping station, and therefore is not desirable.

The annual cost, as will be observed, is a large item, but I believe it is absolutely necessary to clean driven wells at least twice a year. After each cleaning a very perceptible increase is made in the yield of the wells. Sometimes, when pumping hard, finding it impossible to get from a certain number of wells the quantity needed, the cleaning gives a gain of 25% in quantity.

Many of the wells have been in use the last eleven years. Some, not so long in use, have been renewed and the department purposes to renew probably 100 or so the coming year. This renewing consists of drawing the well casing up out of the ground by jacks, attaching a new strainer and driving the casing back in the same place. The strainer is made in the department shop, at a cost of about $5.

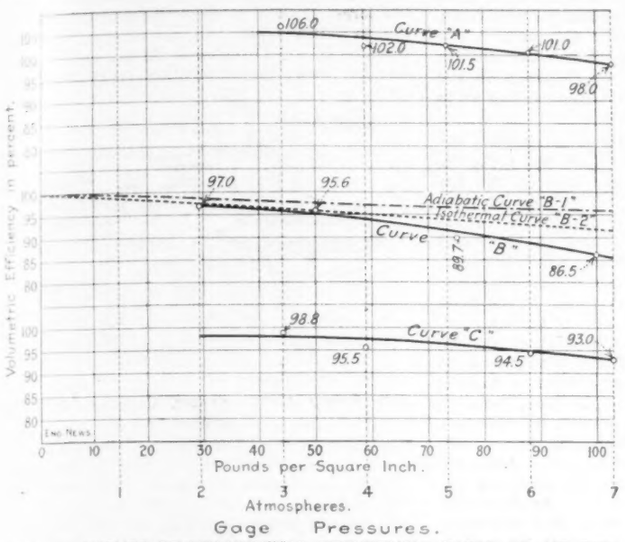


FIG. 7. CURVES OF VOLUMETRIC EFFICIENCY (RATIO OF AIR DISCHARGED TO PISTON DISPLACEMENT). MIETZ & WEISS 8 x 8-IN. COMPRESSOR.

A—At about 410 r. p. m. with pre-compression in crank case.
B—At about 410 r. p. m. without pre-compression in crank case.
B (1)—Maximum theoretical volumetric efficiency attainable at 1.25% clearance and isothermal re-expansion.
B (2)—Maximum theoretical volumetric efficiency attainable at 1.25% clearance and adiabatic expansion.
C—At about 240 r. p. m. with pre-compression in crank case.

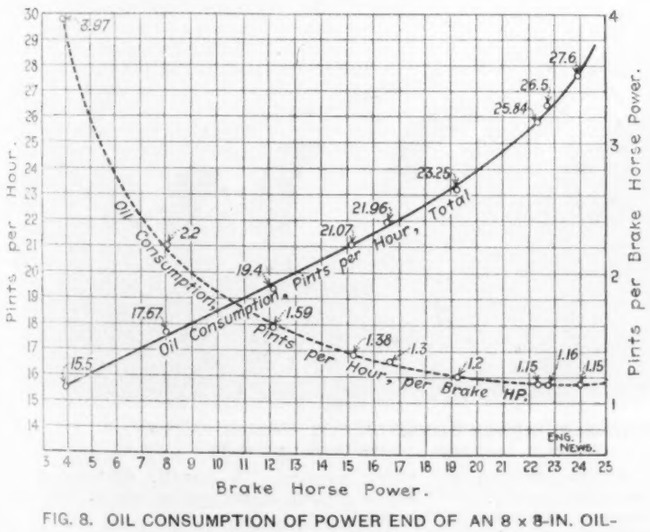


FIG. 8. OIL CONSUMPTION OF POWER END OF AN 8 x 8-IN. OIL-ENGINE COMPRESSOR.

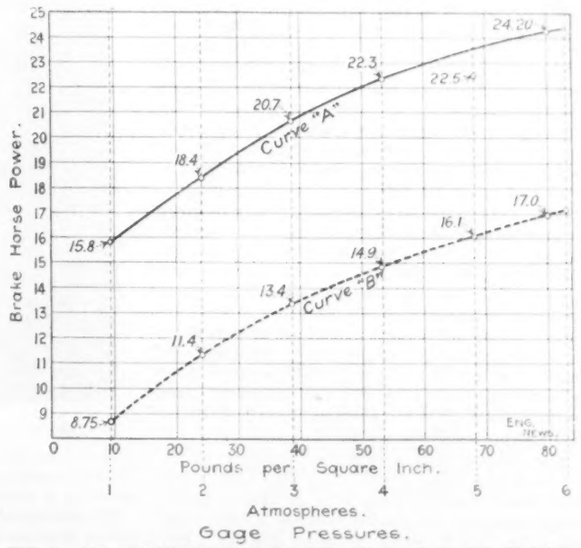


FIG. 9. HP. REQUIRED TO OPERATE AN 8 x 8-IN. OIL-ENGINE COMPRESSOR.

A—B.HP. required to operate.
B—Theoretical HP. required to operate at adiabatic compression.

A LARGE DRYDOCK is to be built in the harbor of Antwerp, according to a recent consular report. The dimensions of the dock will probably be, length, 754 ft.; width at entrance, 88.5 ft., and depth, 32.75 ft. It is expected to be completed in about three years.

PREPAYMENT-TYPE STREET CARS in Buffalo, N. Y., noted in Engineering News, Jan. 6, have been considered so successful that cars on other lines will be rebuilt to make additional ones of this type. The first additional line to have this change is that on Grant St. The platforms are to be lengthened about 2 ft. each and the doors are to be rearranged.

THE NEW WHITE STAR STEAMSHIPS, which are again to break the record for size of ocean vessels, are to be, according to a press dispatch from Liverpool, of 840 ft. length and 78 ft. beam. No attempt will be made to break the speed record, however, and only 21 knots is aimed at in comparison with the 25 knots of the great Cunarders.

CAR SURPLUSES as reported to the American Railway Association's Committee on Car Efficiency on April 15 amounted to 375,770, a larger number of idle cars than has been reported at any time since the business depression. Nearly 70,000 more cars were idle on April 15 than on April 1. The falling off in railway traffic is largely in the shipments of coal, coke, lumber and other building materials.

RAILWAY ACCIDENTS IN ENGLAND have recently been reported in the London "Engineer" as follows:

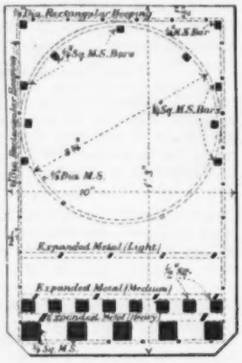
An official return recently issued by the Board of Trade shows that the total number of persons killed on railways in the United Kingdom in the course of public traffic during the whole year 1907 as reported to the Board of Trade was 1,117, showing a decrease of 52 compared with the previous year, and the number injured 8,794, an increase of 1,582. The number of passengers killed was 120, a decrease of 46 compared with the preceding year, and the number of passengers injured was 2,663, an increase of 83. With regard to the servants of railway companies or contractors, the number killed was 454, an increase of 16, and the number injured, 5,894, an increase of 1,439. Trespassers (including suicides) accounted for 447 deaths, compared with 455 in the previous year, and 133 cases of injury, compared with 106.

*See also letter by Mr. George Bowers, M. Am. Soc. C. E., City Engineer, of Lowell, Mass., on "The Permanency of Yield of Driven Wells," Eng. News, March 5, 1908, and an abstract of an article by Mr. Bowers, Eng. News, March 19, 1903 (pp. 263-4). For the article in full, see Jour. N. E. W. W. Assoc., June, 1903 (Vol. XVII., No. 2).

†Superintendent of Water-Works, Lowell, Mass.

A HOOPED REINFORCED-CONCRETE BEAM.

In any phase of engineering construction which usage has not standardized, the constant effort toward the best design places a premium on novelty, often undeserved, but so potent as an advertisement that there will always be on the market numerous devices whose only claim to excellence is their difference from existing practice. In reinforced concrete this attempt to catch the engineering fancy by the unique rather than by the valuable has been forced to the limit, so far indeed that engineers are not surprised at any outlandish design being foisted upon them as the solution of all their difficulties. One of the latest examples of this sort is a reinforced-concrete beam which depends for its novelty on a spirally hooped reinforcement in the upper flange, which, it is claimed, adds materially to the strength and economy of the beam.



A Hooped Reinforced Concrete Beam.

This style of beam has had some popularity in Europe, although it has not appeared on this side of the ocean. Accompanying this article we publish a section through a beam, spirally hooped in the upper flange, which has recently been described in London "Engineering." These girders are to be made in a shop by a manufacturing company in England and are to be kept in stock in standard units to be sold as needed. All mixing and placing of the concrete is to be done by machinery and it is claimed that all voids are filled and that remarkably dense and strong concrete results. The construction, as plainly shown in the cut, consists of a concrete beam heavily reinforced in the tension side with square rods and expanded metal, and in the compression side by a spiral hooping of wire stiffened with small longitudinal rods. The usual vertical stirrups are made by a meshed hooping of ¼-in. rods which enclose the entire beam. In the test of such a beam, 60 days old and made in the regular shop manner, a load of 35,000 lbs. in the center of a 15-ft. span produced no apparent cracking. At 45,000 lbs. the first crack appeared on the lower face, but after strengthening this face (the exact method is not given in the original article), load was again applied until the beam failed on its compression face under a central load of 73,000 lbs.

This beam was, it is claimed, designed for a safe uniform load of 35 English tons over a span of 15 ft.—that is, about 5,200 lbs. per lin. ft. The tests plainly show that it is anything but safe for that load, as it started to fail at a concentrated central load of 20 English tons, or about 45,000 lbs., which would give a bending moment only 20% in excess of the designed safe load. Instead of being safe for a uniform load of 5,200 lbs. per lin. ft. the test shows the safe uniform loading, with a safety factor of three, to be about 2,000 lbs. per lin. ft.

For the very reason that its only claim to an engineer's attention is that it is new, this design will hardly become prominent in this country, but it is worth description because it illustrates the danger of following a theory too far. Because hooped columns have, in the few published tests, shown a marked increase in strength over the straight reinforced columns is no reason for attempting to utilize a similar construction in beams. The tests show that there is no magical property in a spirally wound hoop which can increase the strength of enclosed concrete, but that it is probable that the higher loads withstood by concrete so reinforced are due to the tensional strength of the hooping steel brought into play by the concrete expanding laterally (according to the Poisson ratio) under the load which simultaneously causes it to compress in the line of application of stress. This preliminary compression in the upper flange of a hooped beam complicates the distribution of the moment between the concrete and steel and renders extremely doubtful the utility or at least the economy of so reinforcing a beam. To get the full strength of the concrete the steel must be designed, far above its economical proportion, to take care of this primary deflection in the concrete, always providing that the shifting neutral axis and modulus of elasticity in the concrete do not so complicate the stresses as to make exact analysis impossible.

Aside from this uncertainty as to stresses the intricate network of reinforcement will make the cost of manufacture high and increase the liability of voids in the mass. It is reducing reinforced concrete to an absurdity to weave throughout the mass of concrete all kinds and conditions of steel, the purpose of which is doubtful and the presence of which is an obstruction to the proper laying of the concrete. In the beam shown in the figure there is 3.8% of tension steel, 0.7% of compression steel and 0.5% of vertical steel. If this mass of reinforcement be concentrated in the lower and upper flanges as straight reinforcing metal and not as hooping, with 1% in compression and 3.8% in tension, the safe load on a 15-ft. span, with 640 lbs. in the concrete and 11,000 in the steel, will be about 1,950 lbs. per lin. ft., or practically what the safe load was shown to be for the beam with an extremely complicated system of hooping. And the beam reinforced with straight rods would be assured as to distribution of stress and density of mix.

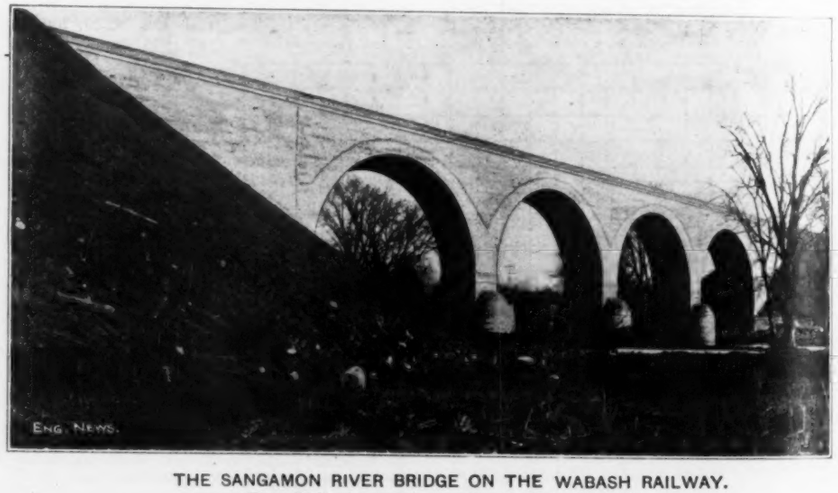
THE SANGAMON RIVER REINFORCED-CONCRETE BRIDGE ON THE WABASH RAILWAY.

We reproduce on this page a view of the finished reinforced-concrete bridge of the Wabash Ry. across the Sangamon River, near Decatur, Ill., the design of which we published in our issue of March 21, 1907, p. 323. This is one of the few large concrete bridges for heavy railway traffic that have been built in this country. It consists of four 82 ft. 5¼-in. skew spans, carrying a double-track main line railway.

The details of the construction were taken up in the previous article. Since then the following items of quantities have become available:

Earth excavation	8,320 cu. yds.
Piling	36,775 lin. ft.
Foundation slabs for piers, concrete	1,300 cu. yds.
Piers proper, with skewbacks, concrete	2,270 "
Arch rings, concrete	2,370 "
Spandrel walls of arches, concrete	2,180 "
Foundations for abutments, concrete	1,580 "
Abutments above foundations, including slabs and intermediate walls, together with spandrel walls, concrete	5,930 "
Retaining walls, concrete	540 "
Reinforcing bars	215 tons
Total cost	$124,000

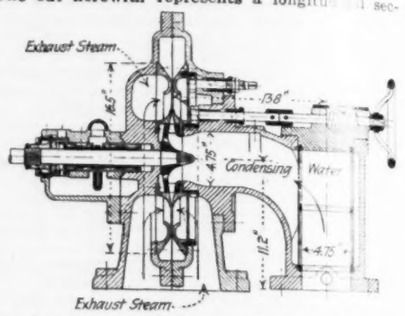
The design and construction have been under the charge of Mr. A. O. Cunningham, M. Am. Soc. C. E., Chief Engineer of the Wabash Ry., who has furnished us with the information herein contained.



THE SANGAMON RIVER BRIDGE ON THE WABASH RAILWAY.
(Four 85-ft. skew spans carrying double track road.)

A ROTARY JET CONDENSER.

A novel type of condenser for steam turbine work has been developed by Mr. O. Kolb, of Karlsruhe, Germany, in the endeavor to reduce the large amount of space required by most of the available types. In its principle the new machine is a jet condenser of the ejector type. The cut herewith represents a longitudinal section through the condenser; we take it from a paper by Mr. H. Meuth reprinted in the "Zeitschrift des Vereins Deutscher Ingenieure." In this section it will be seen that a shaft (at the left) carries a centrifugal pump impeller which takes water from a suction pipe and discharges it through a converging nozzle formed by the entire circumference of the guide casing outside of the impeller. There is a second full-circle nozzle beyond the first, just as in an injector. The contact of steam and water, and therefore the condensation, takes place in the space between the two nozzles. The water leaves the first nozzle in a thin sheet all around the periphery, and enters the flared receiving portion of the second or outer nozzle in the same manner. Its velocity is sufficient to enable it to enter the discharge chamber against atmospheric pressure. The annular discharge chamber is formed in the casing around the outer nozzle.



Kolb Rotary Jet Condenser, Capacity 2,600 lbs. Steam per hr.

The drawing shows a condenser designed to handle about 2,600 lbs. of steam per hour, corresponding to a power output of say 150 HP. Six sizes of the machine are on the market. The impeller shaft for the condenser is in line with the shaft of the steam turbine, and is driven by it through an elastic coupling. In a trial run, a vacuum of 96%, or 28.8 ins. on 30-in. barometer, was obtained when the turbine was running at no load. At full load the vacuum was 5 to 6% lower.

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We referred in this place last week to the danger that the stream gaging work of the U. S. Geological Survey would come to a halt because of the cutting off by Congress of the appropriation for its continuance. Besides this, the appropriation bill as reported out of committee proposed to emasculate the fuel testing and structural material investigation departments of the Survey. The fuel testing division had last year an appropriation of $250,000, which the Committee proposed to reduce by $100,000. The structural materials division had $100,000 last year, which the Committee proposed to cut in two.

The Committee on Appropriations is, very properly, endeavoring to reduce expenses of the Government to counterbalance in some measure the rapidly growing deficit in the Treasury. But there is an economy which saveth at the spigot and wasteth at the bunghole. We are informed that the work of the Fuel Testing division has been made use of by other Government departments in the purchase of coal under a system of definite specifications and tests carried out by this division. The coal for heating 40 Government buildings in Washington was purchased in this way last year, with a saving so great that the Treasury Department has ordered the same system applied in the purchase of coal for postoffices and custom houses throughout the country and the War Department has adopted it for coal purchases for its arsenals at Frankford and Rock Island. The Panama Canal Commission has just let contracts for 400,000 tons of coal to be sampled and tested by the Geological Survey. This is one of the practical results of the Fuel Testing division's work. A number of other practical results, of immense economic importance to the nation, were detailed in a paper by Mr. Herbert M. Wilson in our issue of April 9.

The department of structural materials, also, is carrying out elaborate investigations on the strength of reinforced concrete and has been asked, we believe, to test the cement purchased for use on the Panama Canal.

It will be remembered that these investigations, both in fuels and structural materials, are being carried out under direction of a National Advisory Board, made up of representatives of the principal engineering societies of the country. To a very important extent, therefore, this work is conducted to obtain data useful to the engineering profession and under direction of the engineers of the United States.

The bill as reported by the Committee also contained a clause forbidding any payments to be made to persons who did not give their entire time to the Government service. This clause was aimed at the National Advisory Board, the members of which have been paid $5 a day for the time spent in attending meetings. As most of the engineers who are members of this Board are men whose time is worth $25 to $50 a day or more, it would appear that the Government was not unduly extravagant in compensating this Board.

It is a pleasure to record that when the House took up the appropriations for the Geological Survey in Committee of the Whole on May 4, the spigot-saving economies of the Appropriations Committee were all defeated. The sum of $100,000 was appropriated for stream gaging and the same amount for the work of testing structural materials, while the fuel testing division was allotted $250,000, the same amount as last year. Besides this, the clause cutting off the payment of compensation to members of the Advisory Board was stricken out of the bill.

A new method of determining the sulphur content of iron or steel, devised by a prominent steel works chemist, is described elsewhere in this issue. This new method was devised because it was felt at this plant that the older method of analysis showed an amount of sulphur lower than was actually present. A comparison of the analyses at the close of this article shows that the apprehension was justified and suggests that the trouble may be more than local.

There seems to be a belief in this country, if we rightly interpret the results of an examination of current chemical literature, that in determining the sulphur content of cast irons by the common evolution methods there is an unrecorded amount which is lost in the escape of complex organic sulphides, but that such a loss does not occur in the higher carbon steels at least. There are some experimenters, however, whose investigations* seem to show that sometimes there is such an amount of unrecorded sulphur in determinations for both cast iron and high-carbon steels; that sometimes there is none; and that the chances appear to be about evenly divided as to whether there will be a loss or not.

Are we then getting a higher sulphur content in iron and steel than our specifications call for? If the present limits were fixed from analyses by the older methods, and such methods were uniformly too low everywhere, little harm could result. But if the inaccuracy of such methods is not confined to any class of metal, if the presence or absence of such inaccuracy is as much of a chance as some results show, and if the metal is to be tested by different laboratories at different times and perhaps at widely different parts of the country, then it becomes advisable, for the best interests of all concerned in the product, that more accurate methods than are at present employed should be brought into the daily practice of steel-works chemists.

THE RESERVOIR SYSTEM OF RIVER CONTROL.

It is seldom that we have the privilege of laying before the engineering profession a more important contribution than the paper on the control of the Ohio River, by Marshall O. Leighton, Assoc. M. Am. Soc. C. E., which appears in this issue.

For more than half a century the project of controlling the flow of the Ohio and Mississippi rivers by the construction of reservoirs on their headwaters has been a subject of discussion; but the general opinion of the engineering profession has been that the project was impracticable.

It is, of course, well known that on rivers of small size, such as the minor rivers of New England, extensively used for water power, and some of the streams used for public water supply, it is possible to construct reservoirs enough to nearly equalize the flow at different seasons of the year.

Since large rivers are made up of many small tributaries, it is, therefore, theoretically possible likewise to regulate the flow in any river by building reservoirs on all the tributaries. But there often lies a wide gulf between what is possible and what is financially practicable. The huge volume of water which flows down to the sea when the Ohio or the Mississippi is in flood is too vast to be confined in any artificial reservoirs—at least, that is the way the problem has impressed itself on most conservative engineers. It has been generally accepted, we believe, by the engineering profession, that for the control of our great rivers, the levee system, and not the reservoir system, is the proper engineering solution.

Now comes forward Mr. Leighton with a demand that this old and long accepted tenet of the profession be reexamined. He does not make the claim that the data he has brought together *prove* the reservoir system to be practicable for control of the Ohio River. What he does claim, is that the data which he has collected are sufficient to entitle the reservoir system to a fair and thorough examination. We can no longer lightly dismiss the reservoir plan of control as a mere popular fallacy. A thorough survey must be made to settle the question whether or not the reservoir system is practicable.

The careful reader of Mr. Leighton's paper will perceive that he does not propose to equalize the flow of the great rivers. That were undoubtedly a task too stupendous for man to attempt. The amount of water required to be stored would submerge so much land in reservoirs as to make the scheme impracticable from this consideration alone.

What Mr. Leighton proposes to do is to provide reservoir capacity enough to *store the top wave of the flood, which does nearly all the damage.* The Ohio and its main tributaries would still flow bank-full at times of freshet, and the maintenance of low levees to protect bottom lands and the lower parts of river cities would probably still be advisable. The few feet at the top of the flood wave represent no such great volume of water that its storage in artificial reservoirs would necessarily be impracticable.

On the other hand, this top of the flood wave, released in the drought of summer, when the Ohio is shrunken to its smallest dimensions, would have a very notable effect in increasing the depth of the river and improving navigation.

Still more important is the influence of such storage upon water power. In all the discussion of river control by reservoirs, attention has hitherto been concentrated on flood control and navigation improvement. But the vast potential demand for water power for electric transmission has revolutionized the situation, in this as in other fields of engineering. The figures in Mr. Leighton's paper indicate that the great investment necessary to control the Ohio by reservoirs would create water power of a value exceeding many times its cost. The reservoirs will pay, he maintains, to prevent flood destruction, they will pay well also to benefit navigation in low periods; but in the creation of water power the reservoirs will pay a larger return than any other great engineering enterprise now before the nation.

Doubtless the most surprising thing in Mr. Leighton's paper is the low estimate of cost which he gives for the creation of this system comprising a hundred different reservoirs. His estimate is in round numbers $125,000,000, and it is reached by taking the cost of 97 large reservoirs for water supply and irrigation constructed in recent years and ascertaining the cost per second foot of water stored in reservoirs of various size. With this unit, the cost of the reservoirs of the proposed system is then ascertained.

*Several such are shown in an article by Mr. George Auchy, Chemist, Disston Saw Works, in "The Chemical Engineer," March, 1908.

This method of cost approximation was the only one available and is the most scientific and accurate method that could have been adopted, under the circumstances. It must be recognized, however, that this method of estimating takes no account of local topographic or geologic peculiarities. A reservoir site may appear ideal, judged by the contour lines upon a map, and yet the foundation conditions at the dam site may add enormously to the cost of construction. It has been the general opinion of engineers, we believe, that the local conditions in the southern Appalachians were less favorable for reservoir construction than in the North, where the glacial epoch laid bare the rocks, and formed many natural reservoirs.

Whether the reservoirs proposed by Mr. Leighton could be built for the sum which he names, is a question which could be settled only by careful survey and examination of each of the proposed reservoir sites. It may be that such a detailed investigation would disclose some formidable difficulties in the way of the proposed system of reservoirs; or, on the other hand, more favorable conditions than now imagined may exist, such, for example, as conditions favoring the extensive use of the hydraulic system of dam construction.

It will be apparent, of course, that in investigating the possibilities of the reservoir system, Mr. Leighton was limited to such data as were already on record, supplemented by some rapid general reconnoissance over parts of the country affected. Of course, such an investigation is too limited and imperfect to constitute a basis for final action. It does seem clear, however, that even if the proposed reservoirs should cost twice or thrice the 125 million dollars estimated by Mr. Leighton, the enterprise would still be worthy of ultimate accomplishment. The benefits to result from such a huge system of river control, particularly the creation of valuable water-power, are so vast that a large increase in the estimate of cost may occur without making the project impracticable.

There is one thing, however, that may threaten the project, and that is the filling up of the reservoirs by earth washed from the steep mountain slopes, from which the forest cover has been barbarously removed. If the nation is to stand supinely by and permit the destruction of the last of the forests that protect the Appalachian Mountain slopes,—then, indeed, the problem of river control may become one impossible for the engineer to solve. If the deep layer of earth and debris on the steep mountain slopes is to be washed unchecked into the valleys of creeks and rivers, it will be useless to build reservoirs to store flood water. There is even prospect that the river beds may be so built up by deposited debris as to make the levee system also impracticable. The ruin which this will involve to millions of acres of rich bottom land farms, to the extensive navigation interests on our rivers and to the cities in the Ohio Valley, which have lost many million dollars in the last two years by flood ravages—such ruin is plainly foretold by what has already taken place.

We risk nothing in saying that the unanimous voice of the engineering profession is that the Appalachian forests must be saved from destruction and that their preservation is an essential to future national prosperity. Their preservation is a vitally necessary first step to make river control, either by reservoirs, as Mr. Leighton proposes, or by levees, a permanent success.

And another question arises at this point: Assume for the sake of argument that the reservoir plan of river control is demonstrated to be practicable. Assume that by spending, say, $200,000,000 in building reservoirs on the headwaters of the Allegheny and Monongahela and a dozen other chief tributaries of the Ohio, floods in that river can be kept below the danger line, low-water depths can be increased so that navigation will be stimulated and vast expenditures in dredging and slackwater navigation systems will be rendered unnecessary, while the increased flow in dry weather will improve the quality of the potable water supply in all the cities along the river. Assume, also, that these reservoirs create a water-power amounting to three million horsepower, and capable of yielding an annual income when developed of fifty million dollars. The use of this power will save from consumption some fifteen million tons of coal per annum, and is, therefore, an important means of conserving our rapidly diminishing fuel supplies.

Assume that because of all these considerations, the enterprise is judged one that should be undertaken, the question arises who should or could undertake it and carry it out? Could the cities of Pittsburg and Allegheny, which have been the greatest sufferers from flood damage, undertake the work of reservoir construction on the Allegheny and Monongahela? In order to do it they would have to build reservoirs not only in Pennsylvania, but in New York, Maryland and West Virginia. Is it not clear that these cities, and likewise the State of Pennsylvania itself, is impotent to carry out this work of river control? Its power stops at the State line. That private enterprise would be powerless to conduct the work is evident at a glance. There remains, then, only the Federal Government. If our great engineering problems of river control are ever to be practically solved—and solved they must be if we are to retain national prosperity—then the Federal Government must assume the work. No one questions the necessity that the navigable rivers shall be under Federal control. There is as little reason to question that the whole of our river systems and the entire work of introducing modern engineering systems of river regulation must be assumed by the Federal Government, at least wherever the waters of a stream cross State boundaries so that its control becomes a matter of interstate interests.

We all accept without question the ruling that the Federal Government has entire control over interstate commerce,—the buying and selling and transport of goods passing from one State to another. But surely the water which Nature causes to flow across State boundaries is as potent to carry benefit on the one hand and destruction on the other as any of the goods which are bought and sold. It is as reasonable, therefore, and as much for the general benefit, that the Federal Government should have sole control of interstate waters as of interstate commerce.

LETTERS TO THE EDITOR.

Stadia Surveys in Tropical Jungles.

Sir: Referring to the article by Mr. John K. Flick in your issue of March 26, 1908, and the remarks by Mr. F. Lavis, M. Am Soc. C. E., in your issue of April 23, 1908, both referring to the use of the stadia in tropical jungles I beg leave to state that I made a difficult railway location in the densest of jungle country in the Island of Mindanao, P. I., in 1905-1906.

The survey would have been nearly impossible from an economic point of view had we not used the stadia continually. In such countries, however, care must be taken to use the instruments at those times of the day when heat radiation is at a minimum.

Of the great value of the stadia in surveys in such countries, there can be no question.

Yours very truly,

A. B. Putnam,
Captain, Corps of Engineers.

Riverton, Ala., April 27, 1908.

An Improvement in Locomotive Turntable Installation.

Sir: During the past few years the Louisville & Nashville R. R. has increased the size of its locomotives to such an extent that larger and stronger turntables have had to be installed in a number of terminal yards. Most of these tables are motor-driven and more or less trouble has been encountered in keeping the circular rail in good condition. Theoretically, when an engine is turned, all of the weight should bear directly on the center pivot, while the end wheels of the table are supposed to either clear the circular rail, or just touch it. In practice, however, the engines are not always balanced exactly, so there is often considerable weight on one end or the other, causing the table to turn hard and the motor to slip. To overcome this slipping evil the circular track is sanded, but this makes the table harder to move and rapidly wears out the small end wheels.

A new 75-ft. table was recently ordered for the Montgomery yard and when it was installed it was found that the end wheels were too close to the [illegible] to afford clearance for the motor which had been on the old table. It was then decided to put a second circular track, about 10 ins. inside the wheel track, to carry the motor alone. When everything was ready the motor was attached and its track well sanded and the wheel track was thoroughly greased. The [illegible] has been so satisfactory that the same plan is being adopted for several other tables on the division that are in need of repairs.

Yours truly,

G. K. [illegible]

2104 First Ave., Birmingham, Ala., April 2[illegible]08.

Sensations of Passengers in the Battery Tunnel.

Sir: In your issue of April 23 there is a letter in which Mr. Locke says that I account for the sensation felt in the ears in passing through the Battery tunnel in New York on the ground of difference in elevation. I have never held this view and do not understand how I could have been so misunderstood when speaking before the Brooklyn Engineers' Club. Mr. Locke in his letter has given a theory which I explained fully to a number of gentlemen immediately after the meeting as my opinion of the cause of the peculiar sensation.

Very sincerely,

George A. Soper.

29 Broadway, New York, April 29, 1908.

Destruction of an Old Coast Survey Monument.

Sir: The old hexagonal brick tower, which marked the northerly end of the Massachusetts Base Line of the United States Coast and Geodetic Survey, was destroyed on the night of April 30, being undoubtedly blasted down by some vandals of the neighborhood. This tower was erected in 1844, under direction of A. D. Bache, Assistant on the Coast Survey, and has long been a conspicuous landmark. It stood on the easterly side of the Providence Division of the New York, New Haven & Hartford R. R. about a half mile southwest from the village of East Foxboro. As the base line was laid out so as to follow the long tangent of the railroad, the tower was conspicuous from a long distance down the line.

Fred. J. Wood.

Foxboro, Mass., May 4, 1908.

THE SPRING MEETING OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

The thirteenth general meeting of the American Electrochemical Society was held April 30, May 1 and 2, with various sessions in Albany, Troy and Schenectady. The attendance was large, even at the opening session, and about 140 members and guests were registered during the meeting. The secretary's report showed a present membership of 715 and a steady gain in progress of about 10% annually.

At one of the business sessions a prize of $500 was offered to members of the society by the Pacific Coast Borax Co. for a solution of the problem of making by an electrochemical process, ferro-boron from borate of lime. This alloy has a possible field of use in making boron-steel with properties similar to vanadium-steel and other alloy-steels.

Dr. F. A. Wolff, of the Bureau of Standards, Washington, D. C., addressed the convention and outlined his opinions as to the advisability of redefining the standard of electromotive force, current and resistance. He advocated making the volt and ohm standards which would allow the ampere to result by Ohm's law from the relation of the other two. These opinions, it should be remarked, are not universally shared by physicists and engineers, many of whom would define the volt and ampere and allow the discrepancies to pass into the derived ohm. A committee was appointed, consisting of Messrs. T. W. Richards, Carl Hering, Edward Weston, and H. T. Barnes, to represent this society in forthcoming conferences on these standards.

The following officers were elected for the coming year:

President, E. G. Acheson, Niagara Falls, N. Y. Vice-Presidents, C. P. Townsend, Washington, D. C.; C. A. Doremus, New York City; W. R. Whitney, Schenectady, N. Y. Managers, F. A. J. Fitzgerald, Niagara Falls, N. Y.; A. von Isakovics, Monticello, N. Y.; S. A. Tucker, New York City. Treasurers, P. G. Salom, Philadelphia, Pa.; J. W. Richards, So. Bethlehem, Pa.

The vice-presidents and managers are additional to a like number whose terms did not expire this year.

At the first session held at the Hotel Ten Eyck, Albany, Mr. H. L. Bronson, of McGill University, described the construction and calibration of resistances of the order of 10,000 megohms. These were in brief ebonite cylinders containing minute quantities of radioactive salts so that the air or gas in the cylinder held certain emanations. It has been known that these emanations give the gas a slight conductivity or a high resistance which appears to be constant and to conduct electricity according to Ohm's law for a small range of voltages, say up to 40. Mr. R. W. Boyle, of McGill University, described experiments showing that emanations from radioactive substances behaved exactly as gases so far as concerns their properties of being absorbed by substances like charcoal.

THE CORROSION OF IRON.—A large part of the interest of the first day's session centered around the papers on the corrosion of iron and steel, notably the presidential address of Prof. C. F. Burgess and Mr. Richard H. Gaines' extracts from a report to the New York City Board of Water Supply on the corrosion of the Rochester water supply conduit.

Professor Burgess, in his address, held that far more attention had been paid in the past to the designing of steel and iron structures to obtain the proper strength in their respective parts than had been paid to the real preservation of the completed structure, in which a rate of decay would be found from 1 to 20% per year. It was held also that there was need for far more experimental research to accumulate proper data before electrochemists could hope to solve the problem thrust upon them by those who believed that rusting was primarily an electrolytic phenomenon. In speaking of the corrosion of underground structures, Professor Burgess took opportunity to contradict the widespread opinion that when the path of an electric current is from the electrolyte to the iron that the iron cannot corrode, for such cathode corrosion has been shown repeatedly by laboratory experiments. The result is perhaps attained by a reducing action—a breaking up of certain protective layers that may be at the surface of the iron—yet all too little was known of cathode corrosion under actual circumstances. In treating true galvanic action (where iron was in contact with other metallic substances and both in contact with an electrolyte) as contrasted with the corrosion caused by the leakage of stray currents, Professor Burgess reviewed the work of Prof. W. H. Walker, A. S. Cushman and their co-workers.*

Several microphotographs were shown of electrolytically-refined and Swedish iron to illustrate the contention that slag spots in the latter might contain carbon and account for initial corrosion as well as the somewhat greater and more localized pitting of the Swedish iron under electrolysis.

Professor Burgess further divided electrolytic corrosion causes into two classes where an e. m. f. was set up by a strain in the metal beyond the elastic limit and where temperature differences caused such voltages. The former action was given more extended discussion, and this part was a defence and an extension of results published by Mr. Carl Hambuechen in the University of Wisconsin bulletins showing that the potential differences of the stressed iron to a solution as compared with a normal iron were positive and proportional to the strain. In several curves exhibited the e. m. f. values closely followed the eccentricities of the strain curves.

Mr. Hambuechen's work had previously been severely criticized by Prof. W. H. Walker and others as yielding impossible results, chief among which may be mentioned the claims that his voltages found were three or four times those that could possibly be developed from the theory. Professor Burgess held that iron stressed beyond the elastic limit developed certain slip or cleavage planes of crystals and showed microphotographs to sustain that view. In such an event, among other effects, the potential energy of straining the iron might be present as increased e. m. f.'s at these localities. He stated that laboratory work showed that, in getting the potential of such a specimen of iron, what was obtained really was the potential of a great number of the most electropositive points, which would account for the excessive values.

The most striking pictures and specimens shown during this address were of some test specimens which had been stretched beyond their elastic limit and "necked down." These test pieces had afterward been turned down to uniform size, polished and subjected to active corrosion. The bars were eaten away much more rapidly within the permanently strained parts. Similar experiments with pieces subjected to torsion developed also lines of marked pitting suggesting the twisted condition of the specimen. Such pieces immersed in an electrolyte developed hydrogen bubbles on the unstrained areas and showed free surface where the torsion was greatest. This was held to indicate that the unstrained parts of the bar were acting as anodes in an electrolytic action, that e. m. f.'s were developed in the strained iron assisting in its solution. A punched piece of boiler plate was similarly tested and the greatest corrosion was close to the hole (where the stress was greatest), although deep lines were brought out which were cycloidal in direction, having their source at the punched hole. Pieces of hardened tool steel showed a series of ramified corrosion lines about the surface, while the same steel annealed failed to develop them on corrosion.

Toward the close of the address the effect of temperature differences in producing e. m. f.'s was very briefly discussed with particular reference to locomotive boiler tubes. Here differences of potential were observed between parts of a system increasing with increased pressure, but decreasing as the air was boiled out of the water and not replaced.

(To be completed in our next issue.)

*This results obtained by Prof. W. H. Walker, A. S. Cushman and the other prominent workers in this subject were presented in an article in Engineering News of Sept. 26, 1907.

OUTLINE OF THE NEW WATER SUPPLIES FOR OAKLAND, CAL., AND OTHER CITIES ON THE EAST SHORE OF SAN FRANCISCO BAY.

By PHILIP E. HARROUN,* M. Am. Soc. C. E.

There exists to-day in the cities of Oakland, Berkeley, Alameda, Emeryville, Piedmont and from Richmond on the North to San Leandro on the South along the Eastern shore of San Francisco Bay, a situation which is unique in the history of American water works. Before the San Francisco earthquake and fire, the population of this section was about 150,000, with a normal increase of about 18,000 per annum, and the total water supply available from all sources about 16,500,000 gals. per day. Although at that time the margin between the consumption and available supply was small, there was still sufficient reserve to provide for, with care, the normal increase in population until such time as new supplies could be developed if promptly undertaken. Such work was begun early in April, 1906.

FIG. 1. PRESENT AND PROSPECTIVE SOURCES OF WATER SUPPLY, PEOPLE'S WATER CO., OAKLAND, CAL., AND VICINITY.

On April 18, 1906, occurred the earthquake. The effect of this was to immediately and permanently increase the population more than 100%. That there was not an immediate water famine was due to the fact that it was impossible to house the people and water was required only for their personal use. As fast as houses were built, the people became regular consumers with the normal per capita consumption and this housing has been and is progressing at the rate of 50,000 per annum.

The work begun for the development of the new supplies early in April, 1906, consisted in the organization of both office and field forces for the study of the problems involved. Work was carried on by these forces until July 20, 1906, when it was abruptly terminated, owing to the two corporations supplying water having entered into a contract of sale to the People's Water Co., which contract carried no provision for the prosecution of this work. The sale was ultimately concluded Jan. 1, 1907, when engineering operations were immediately resumed, to be carried on continuously since.

Because of the urgency of the situation, it was necessary that the general scheme for the increased supplies be determined at the inception of the work, that construction might be immediately undertaken. In consequence of this, many of the plans presented are tentative, to be modified as future investigations may indicate. This is specially true regarding the determination of those matters based on hydrographic and meteorologic studies, where the data available are insufficient for a final determination of the questions involved. These studies are still in progress and by the time it becomes necessary to make a final decision the data will be available for the solution of the problems.

The old works and new scheme for securing the proposed increase in water supply are outlined on the map, Fig. 1. The present supplies are drawn from Lake Chabot, and the Alvarado, Fitchburg and San Pablo No. 1 Pumping Plants, together with some small supplies from the high

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hills immediately behind the cities and serving the more thinly settled high sections.

The new project has in view the development of temporary supplies necessary to meet the increased demand until the permanent works can be put in service. This increase in the permanent supply is to be obtained through the conservation of the runoff from about 108 sq. mi., including Chabot, of drainage area in the hills immediately back of the cities to be supplied. Meteorological and hydrographic investigations, carried to date, have provisionally indicated that on 80% conservation of the runoff the net increased yield will be 21,000,000 gals. daily. This is based on the recurrence of the most unfavorable 17-year rainfall period which has occurred since 1849. This increase will give a total yielding capacity for the entire system of about 37,000,000 gals. daily.

On Pinole, San Pablo and San Leandro creeks, as indicated on the map, are to be constructed large reservoirs. The San Pablo and Pinole reservoirs being at the same elevation will be interconnected and to a great extent act as one. Into the upper San Leandro reservoir will be diverted the runoff from the 2.64 sq. mi. drainage area of Las Trampas Creek. In order to compensate Lake Chabot for the drainage area cut off by Upper San Leandro Reservoir, there will be diverted into it the runoff from 4.42 sq. miles of the Bolinger Creek drainage area, 8.47 sq. mi. of the Crow Creek area and 4.42 sq. mi. of the Cull Creek drainage area.

In delivering these supplies to the distribution system, it has been decided to tunnel directly through the high intervening mountains of the coast range instead of using long pipe lines or open conduits as would otherwise be necessary in following the natural contours of the bay drainage. This gives an ideal delivery, as such construction is as permanent as human effort can make it, is as little liable to interruption from earthquake or other cause as any construction can be made, and, owing to the very short distance thus secured between the reservoirs and the distribution system, it gives the great advantage of bringing the supplies held in these reservoirs at once to the distribution point, making it possible to distribute by gravity over a much larger area than it otherwise would and giving much greater and effective pressures.

It will also be observed that the reservoirs group themselves into two large divisions, north and south, immediately contiguous to and discharging into opposite ends of the distribution area, as practically the entire region served lies between these two major sources. In consequence of this, all large pipes of the distribution system will be fed from both ends, much increasing their effectiveness and making it possible to close off either source if necessary without cutting off the supply in any section, and making it practically impossible to interrupt the supply through earthquake, fire or other cause.

These reservoirs will serve by gravity two zones—Lake Chabot on the south with a clear water elevation of 168 ft., is to be repumped to 198 ft., and San Pablo and Pinole at an elevation of 198 ft. will serve all the intervening section and north to the Richmond District. Upper San Leandro Reservoir, with an outlet at an elevation of 314 ft., will serve a second zone. A third zone will be controlled from Berryman Reservoir, at 503 ft. elevation, while the few sections higher still will continue to be served by the works already supplying them supplemented by pumping from the lower zones where necessary.

The works undertaken to temporarily meet the increasing demand until the permanent structures are completed are two; the San Pablo No. 2 Plant and Pipe Line and the 40th St. Pump Station. In the cone which extends from the point where San Pablo Creek breaks through the hills to the Bay Shore there have been drilled 9, 10 and 12-in. wells to an average depth of 436 ft. These wells are cased with riveted steel slip-joint casing, perforated through the water-bearing strata. These wells upon individual test gave discharges ranging from 120 to 286 gals. per min., with one exception, where the discharge ranged between 74 and 85 gals. per min.

The water will be raised from the wells by compressed air and discharged into an open flume in which it will flow by gravity to the sump at the pump house. Here it will be picked up by the main station pumps.

Twelve and one-quarter miles of 24-in. riveted steel pipe, 3-16-in. thick, are being laid between this plant and the Claremont Reservoir. The size of the pipe has been selected with reference to its ultimate, not its temporary service, as, upon completion of the permanent works, its flow will be reversed and it will be used for supplying the lower pressure zone throughout this district.

The 40th and Diamond emergency work is a booster plant, taking Lake Chabot and Alvarado water from low-service main and boosting into that section controlled by the Claremont Reservoir. No new equipment was had for this plant with the exception of boilers.

Of the permanent works, the San Pablo Reservoir will be formed by an earth dam 124 ft. high above the normal surface of the stream, while the concrete cut-off wall will extend to bed rock 70 ft. below same. Its length on the crest is 1,160 ft., crest width, 25 ft., slopes up-stream

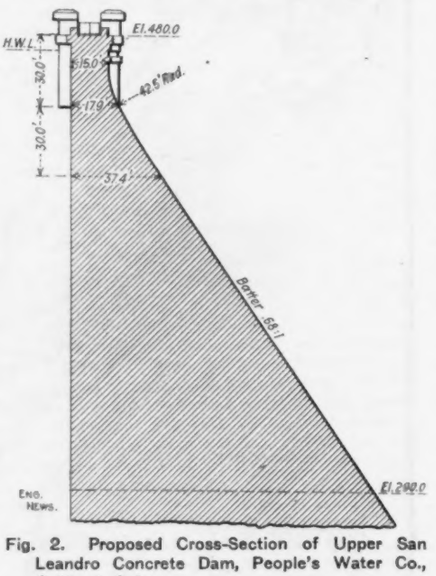

Fig. 2. Proposed Cross-Section of Upper San Leandro Concrete Dam, People's Water Co., Oakland, Cal.

from 2:1 to 3:1; down-stream, 2:1, broken by a 6-ft. berm 59 ft. below the crest. The cut-off wall will be carried from bed rock to within 5 ft. of the crest and will be backed by broken stone, which will also extend under the lower half of the dam to its toe for drainage purposes. The dam will contain 842,000 cu. yds. The flow line is 10 ft. below the crest of the dam. The wasteway consists of a concrete weir 274 ft. long on the crest over which the flood waters spill into a funnel-shaped chute leading to a horseshoe-shaped tunnel, 16½ × 19½ ft., and 1,400 ft. long, passing through solid rock around the south end of the dam to the channel below. With 5 ft. of water over the crest of the spillway the discharge will be 12,000 cu. ft. per sec. The tunnel will also be connected with controlling works whereby the reservoir may be drawn down at any time. The reservoir formed by this dam has a storage capacity of 656,000,000 cu. ft.

The Pinole Reservoir will also be formed by an earth dam. Its height will be 112 ft., length, 800 ft., volume, 425,000 cu. yds. Its cross-section and structural details are the same as those for San Pablo dam. This reservoir will have a storage capacity of 305,000,000 cu. ft.

These two reservoirs are at the same elevation and will be interconnected so that they will to a great extent act as one. The connection consists of a tunnel 5,510 ft. long, leading out from the Pinole Reservoir with the necessary controlling works. From the southerly end of this tunnel extends a riveted steel pressure pipe, 27 ins. diameter, to the San Pablo Reservoir.

The outlet from both Pinole and San Pablo Reservoirs will be through a tunnel 1,600 ft. in length with a vertical shaft on Wild Cat Creek 305 ft. deep, through which, after having served construction purposes, will receive the waters of Wild Cat Creek. This tunnel will deliver the water to the filter plant and distribution system at North Berkeley. In this case, as is also true of the other tunnels, the hydraulic requirements are met by adopting as small a section as it is possible to drive. As the element of time is also of great importance, that section has been adopted which will permit of maximum progress at least cost, considering the materials to be penetrated. This is of the horseshoe form, 5½ × 6½ ft.

Muck will be handled by three compressed-air locomotives, two operating through the two portals and the third serving the two headings driven from the shaft. Compressed air will be taken from the air main at line pressure and by three boosters raised to 1,000 lbs. per sq. in. for locomotive use. The locomotive tank capacity is sufficient for one round trip on full charge. The boosters, except that at the Berkeley portal, which is steam driven, are electrically driven by motors taking current from the main station transmission lines.

The Upper San Leandro Dam will have a height of 192.5 ft. above the bed of the creek. Its length on the crest will be 675 ft. It will be straight in plan, with a gravity section. The provisional section is shown herewith as Fig. 2. The spillway will be of the same type as that designed for the San Pablo and Pinole structures, the tunnel passing through the ridge under the south abutment.

This dam will form a reservoir covering 1,100 acres, with a depth of water at dam of 185 ft., giving a storage capacity of 2,232,000,000 cu. ft.

The runoff from 2.64 sq. mi. of the drainage area of Las Trampas Creek will be diverted by a small dam and led by 5,000 ft. of open conduit to the headwaters of San Leandro Creek, whence it will flow by gravity to this reservoir.

The water will be brought from Upper San Leandro Reservoir directly through the hills to the distribution system by means of a tunnel 12,400 ft. long, which will have a shaft on Grass Creek 170 ft. deep. This tunnel will be of the same size as those for San Pablo and Pinole. From the tunnel outlet a gravity conduit will lead to a filter plant above Melrose, from which a pressure pipe is to lead to Claremont Reservoir with an outlet connection to Central Reservoir.

The Cull-Crow-Bolinger system consists of diverting the runoff from 4.92 sq. mi. of the Bolinger drainage area into Crow Creek, picking up the same, together with the Crow Creek waters and passing them into Lake Chabot by tunnels, intercepting on the way the Cull Creek waters. The equalizing and diverting dam on Bolinger will have a maximum height of 60 ft. It will be a composite structure of earth and concrete, forming an equalizing reservoir of 15,000,000 cu. ft. capacity. From this reservoir the waters will be carried in an open conduit about two miles long, thence through a tunnel 1,620 ft. long will enter the Crow Creek drainage area. From this point it will flow by gravity down the natural stream channel to the Crow Creek Dam.

The diverting dam on Crow Creek will be 60 ft. high and 740 ft. long. Its character and slopes will be similar to the San Pablo and Pinole structures. The equalizing reservoir formed by this dam will have a capacity of 24,000,000 cu. ft. From this reservoir, the water will pass into San Leandro Creek, picking up the Cull waters on the way through a shaft 125 ft. deep.

The Cull diversion will be effected by a composite dam 35 ft. high and 290 ft. long. This will create a precipitating and equalizing reservoir with a capacity of 6,700,000 cu. ft., from which an open conduit 500 ft. long will conduct the water to the tunnel shaft.

The Crow-Cull-San Leandro Tunnel will have

a length of 12,920 ft. and is 5½ × 6½ ft. in section, as are the others previously described.

These filter plants will be constructed, one at Lake Chabot to replace the present inadequate plant, the second back of Melrose, in the hills at an elevation of about 325 ft., to handle the water from the Upper San Leandro Reservoir, and the third at the North Berkeley portal of the San Pablo Tunnel, to handle the waters from the San Pablo and Pinole reservoirs. The open rapid mechanical type will probably be adopted, but final decision on this matter, as well as the details and plans, will not be reached until the completion early in the summer of the experimental runs.

The capacities of the filter plants will closely approximate the following requirements:

	Capacities, million gallons daily. Summer.	Winter.
Chabot	15.4	12.7
North Berkeley	16.6	13.7
Melrose	7.25	6.0

In order to increase the storage capacity within the limits of the cities and also to raise the pressure derived from Lake Chabot and the Alvarado sources, the Central Reservoir is to be built. This reservoir has a high-water elevation of 198 ft. and a capacity of 150,000,000 gals. It will be concrete-lined and covered with a timber roof.

This reservoir, having an elevation the same as that proposed for the clear-water basin of the North Berkeley filter plant, will admit of the entire intervening territory being supplied under a common pressure from these two independent sources.

To boost the Lake Chabot and Alvarado waters to this reservoir, the 24th Ave. Pumping Station is being built, with a capacity of 24,000,000 gals. daily. The pumping engines consist of three horizontal cross compound condensing Reynolds-Corliss type duplex double-action pumps, each of 8,000,000 gals. capacity, against a head of 134 ft. They are made by the Allis-Chalmers Co. and have a guaranteed duty of 135,000,000 ft.-lbs. per 1,000 lbs. steam. Fuel oil will be used.

Large interconnecting pipes are to be laid between the various reservoirs and pumping plants, as shown in Fig. 1.

This work has been carried on under an organization consisting of Mr. Arthur L. Adams, M. Am. Soc. C. E., Chief Engineer; Mr. Philip E. Harroun, M. Am. Soc. C. E., Assistant Chief Engineer; Mr. F. T. Oakley, M. Am. Soc. C. E.; Mr. W. W. DeBerard, Assoc. M. Am. Soc. C. E.; Mr. G. C. Stevens, Mr. Langdon Pearse, Jun. Am. Soc. C. E., and Mr. August Kempkey, Jr., Jun. Am. Soc. C. E., Assistant Engineers, together with the necessary field and office forces.

A DESTRUCTIVE DUST EXPLOSION in the shipping department of the Sharpless Extract Co., at Chester, Pa., April 28, seriously injured nearly a score of workmen and caused a loss of $150,000.

A NEW 10,000-HP. GENERATOR BURST while being tested recently at 400 revolutions per minute in the station of the Niagara Falls Hydraulic Power Co., of Niagara Falls, N. Y. One man was killed and another was seriously injured.

THE JAPANESE CRUISER "MATSUSHIMA" was sunk on April 30 by an unexplained explosion of her stern magazine; 240 members of her crew, officers and men, are reported lost or missing. The vessel formed part of the training squadron cruising off the Pescadores Islands between the west coast of Formosa and the coast of China.

IN AN INTERURBAN TROLLEY CAR COLLISION on April 28 on the Detroit, Jackson & Chicago Ry., 25 miles west of Detroit, it is reported that nine persons were killed and about thirty injured. According to a statement in the Philadelphia "Record" the cause was neglect of orders by the motorman of the westbound limited, who, remaining at his post, was crushed.

DURING A SEVERE STORM AT DEWITT, IOWA, April 24, the railway bridge over Honey Creek was undermined by floods and gave way under a heavy freight train, the engineer and fireman being killed; a 30-ft. section of the Crystal Lake Dam went out, reducing the lake to a ditch, and finally the town was visited by a tornado, one of whose vagaries was the placing of a barn across the tracks of the Chicago, Milwaukee & St. Paul Ry.

A NEW CONCRETE GRAIN ELEVATOR at Keewatin, Ont., met with a peculiar accident on April 29. According to the Montreal "Gazette" the side of one of the bins fell out, and 50,000 bushels of wheat went with it. The elevator is stated to be of 750,000 bushels capacity, and to be still in the hands of the contractors, not having as yet been turned over to the owners after completion.

THE CHICAGO GARBAGE REDUCTION PLANT described in our issue of March 12 was badly damaged by fire following an explosion of naphtha on May 1. The building in which the dried garbage was treated by naphtha for the extraction of oil was completely wrecked, but the other buildings were saved. One man was killed, and others who are missing are thought to be buried in the wreck. Several were burned. It is thought that the accident may have been caused by employees smoking, for while this is forbidden it has been found difficult to enforce the rule. Mr. Turner, secretary and general manager of the concern, states that the plant will be rebuilt on a larger scale.

A HOTEL FIRE at Fort Wayne, Ind., early on the morning of May 3, caused the death of 15 to 20 guests. The New Aveline Hotel, many decades old, was a six-story brick-faced structure. At 3.30 a. m. the electric elevator refused to work, and a few minutes later flames came up the elevator shaft. They spread to the upper floors so rapidly that most of the inmates were cut off from stairways and fire-escapes. The factory inspector is quoted in the New York "Sun" of May 5 as saying that the hotel was considered somewhat dangerous, but its condition did not warrant condemning it.

It was cut up by a great number of narrow stairways, which naturally made it difficult to find exits in case of a fire. There were three fire-escapes, which would be ample if there were enough means of reaching them.

The proprietors had been warned some weeks ago about the condition of the building and had been ordered to put more lights in the halls.

THE THIRD SERIOUS ACCIDENT to the British navy within a month occurred on the morning of April 28, when the torpedo boat destroyer "Gala" was cut in two and sunk with Engineer Lieut. Frank A. Fletcher on board, off Kentish Knock, in the North Sea, by the scout "Attentive." It is only a few days since the armored cruiser "Gladiator" was run down and completely wrecked in the Solent by the Atlantic liner "St. Paul," and three weeks before this the torpedo boat destroyer "Tiger" was rammed by the cruiser "Berwick" during manoeuvers of the Portsmouth Division of the home fleet off the Isle of Wight.

A PECULIAR RAILWAY ACCIDENT blocked all four tracks of the Pennsylvania R. R. between New York and Philadelphia on the morning of April 24. A local five-car passenger train filled with commuters for Jersey City had gone a very short distance beyond the station at Elizabeth, N. J., when the axle on one of the forward cars of a freight train loaded with brick and iron pipe, running on a parallel track and in the same direction as the local, broke. The car plunged across and struck the second coach of the passenger train, throwing it over on its side; the coach immediately following also left the rails but was not overturned. The former was thereby left hanging over a 15-ft. embankment, supported only by a telegraph pole; had this given way, severe casualties to the passengers within must have ensued. Fortunately but one serious injury and no fatalities are reported. Of the freight train, more than a dozen cars were piled up, bricks and pipe were widely scattered, forcing a complete tie-up for several hours.

PANAMA CANAL EXCAVATION during April fell slightly behind the monthly record made in March, 1908, but exceeded all other previous monthly totals. The excavation for April, in 25 days, was 3,296,096 cu. yds., or 131,844 cu. yds. daily, as against 3,480,270 cu. yds. for the 26 working days of March, a daily average of 133,856 cu. yds. The rainfall is beginning its spring increase, being 1.9 ins. in April as against 0.99-in. in March. The detail figures in cubic yards for the March and April excavations are given below:

Steam shovels.	April.	March.
Culebra Division	1,170,892	1,216,264
Gatun Locks	196,100	202,762
Chagres, Mindi, Miraflores and Cardenas Hill	500,460	487,546
Dredges.		
Colon	496,366	515,223
La Boca	676,539	783,281
Total, Canal Prism	3,040,366	3,205,076
Accessory works outside the Canal Prism	255,730	275,194
Total excavation	3,296,096	3,480,270

THE CLEVELAND STREET RAILWAY FIGHT, popularly known as the three-cent fare campaign, has come to end, with victory for Mr. Tom Johnson, Mayor of Cleveland. The Cleveland Electric Railway Co. and also the several companies organized by Mayor Johnson and his friends in lieu of municipal ownership have assigned their interests to the Cleveland Railway Co., which in turn has leased the consolidated properties to the Municipal Traction Co. The latter is a holding and operating company, composed of five self-perpetuating directors, no one of whom can transfer any stock without the signature of the other four. The lessee must keep the property in good repair and meet all other charges, besides paying 6% interest on the stock of the same or all of the consolidated companies. The valuations of the several companies are reported as follows: Cleveland Electric Railway Co., $12,870,000; The Forest City Railway Co., $1,600,000; The Low-Fare Railway Co., $70,000; The Neutral Railway Co., $150,000. In addition, there are $9,000,000 of Cleveland Electric bonds, which brings the total capitalization, at consolidation, up to $23,690,000. New stock to the amount of $15,000,000 may be issued. In case of failure to meet this capital charge the property will revert from the holding company to the consolidated company. In such an event the consolidated company must sell six tickets for a quarter. The lease to the holding company puts no limit on the fares to be charged by it, but prohibits profits to the company. It is understood that 3-cent fares will be charged. On the day after the agreements were signed no fares were charged on any of the street railways, and it is said that hereafter the day of closing the agreement (April 27, 1908) will be celebrated in like manner. The Cleveland street railway fight has extended through about seven years and has included numerous lawsuits and several mayoralty elections in which last Mr. Johnson has been successful every time. In one of the recent court decisions important franchises of the Cleveland Electric Railway Co. were decided void, which, with the defeat of Congressman Burton by Mayor Johnson in the last mayoralty election, went far towards bringing the fight to a close, and of cutting the price allowed for the company's stock to $55, as compared with $105 asked at an earlier stage of the negotiations.

A notable incident of the legal fight was the overthrowing of the city charter of Cleveland and with it the machinery of municipal government of the whole state of Ohio, on the ground of unconstitutional classification of municipalities to avoid the prohibition against special legislation. The new Municipal Code of Ohio greatly curtailed the powers of the mayor, particularly the mayor of Cleveland, but neither that nor aught else has availed in the fight of Mayor Johnson and the people of Cleveland to control the street railways of the city.

THE BROOKLYN EXTENSION OF THE NEW YORK subway was opened from Borough Hall to Atlantic Ave., Brooklyn, on May 1. This brings the New York subway system into direct connection with the Long Island R. R., whose new station at Atlantic Ave. and Flatbush Ave. promises to become the chief terminus of all Long Island railway traffic. The opening of the present addition to the system completes the original Contract No. 2, as the Brooklyn Extension was known. This includes about a mile of line in Manhattan borough, southward from City Hall to the Battery, with a double-track loop at the latter point, thence passing under the East River by two single-track shield-driven tunnels to Joralemon St., Brooklyn, thence easterly along Joralemon St., Fulton St. and Flatbush Ave. to Atlantic Ave. The contract for the entire Brooklyn Extension was taken at a figure far below the estimated cost and still further below the actual cost, by the Rapid Transit Subway Construction Co., composed of the same interest as the Interborough Rapid Transit Co., which operates the subway. The contract provides for both construction, equipment and operation (see Eng. News, Jan. 21, 1904, pp. 52-55). The contract price was $2,000,000 for construction and $1,000,000 for real estate and terminals, against an estimated cost of $8,000,000 to $10,000,000.

With the completion of this work, subway construction in New York City is temporarily at a standstill. A year or two past the question of extending the Brooklyn line along Flatbush Ave. to Prospect Park was strongly agitated, but nothing came of the matter. More recently a subway along Fourth Ave., Brooklyn, from the eastern end of the new Manhattan Bridge (now being built) was much discussed, and finally was authorized by the Board of Estimate. Plans have been prepared for this route and it is said contracts will soon be let, although the city's financial condition does not permit of any large expenditures for construction. A second north-south subway in Manhattan has also been authorized, but its realization appears to be more remote; its route is up Broadway and Lexington Ave. to the Bronx, with two branches north and east in the latter borough. The State Legislature has passed a bill for a constitutional amendment which purposes to exempt bonds for self-supporting improvements from the sum limited debt of the city. This must again be passed at the next session and then must be passed by popular vote at a general election. If passed, it will render available large sums of money for subway and dock construction, both of which classes of work are now badly hampered in necessary development by the fact that the city's debt has practically reached the constitutional limit.

A REMARKABLE FAST LONG-DISTANCE RUN was made on the Pennsylvania R. R. on April 26, when a train made up of two standard baggage cars and two sleepers made the 468 miles from Pittsburg to Chicago in 462 minutes, an average speed, including stops, of 60.8 miles per hour. The train was a special, carrying a theatrical troupe, and was scheduled to make the trip in 7½ hours, but the Pennsylvania 18-hour New York to Chicago train had the right-of-way at several places, thereby causing the special to lose considerable time.

THE LOETSCHBERG TUNNEL HEADINGS were advanced 922 ft. in February (N. heading 525 ft., S. heading 397 ft.) and 590 ft. in March (all in N. heading). The Goppenstein avalanche of Feb. 29, 1908, which demolished the contractors' boarding-house at the south end of the tunnel and killed a number of men, stopped the advance of the south heading throughout March, although work on the top (second) drift and the full-section work was resumed March 10. The total length of headings on April 1 was: N. heading, 6,334 ft., S. heading 5,136 ft., total 11,470 ft. The whole distance between portals is 45,051 ft.

ROADBUILDING IN NEW YORK STATE is progressing at a rapid rate under the supervision of the State Engineer, whose office has recently issued the following statement:

Since 1898 the state of New York has completed 978 miles of improved highways at state, county and town expense. The state now has 1,034 miles of roads under contract and 977 miles of roads waiting the letting of contracts. In 1906, the state appropriated for highway improvement $5,000,000; in 1907, $3,000,000, and in 1908, $3,000,000, $1,000,000 of which is available now and $2,000,000 available in the fall. The appropriation therefore is as large this year as it was last. Three counties in the state have completed and under contract at least 140 miles; one county 100 miles, two counties 90 miles, two counties 80 miles, two counties 60 miles, five counties 50 miles, four counties 40 miles, four counties 30 miles and 27 counties, one-half the entire number of the state, less than 30 miles each. The present statute is so drawn that the mileage to be improved in any one county in each year is dependent not upon equitable distribution to each county, but on a ratio determined by the number of miles on the highway map plus the total number of miles of new road completed in each county. It is very evident that the statute so drawn carries larger annual improvements to the counties having the large mileage on the map plus the large mileage improved, and that they are being taken care of faster than the other counties. The law is repealed by the new highway code, but the repeal does not go into effect until January, 1909.

THE CANADIAN BOUNDARY is to be surveyed and marked by a joint commission of Canada and the United States, according to a treaty signed on April 11 and ratified by the United States Senate on May 4.

THE PITTSBURG TYPHOID FEVER SURVEY (see Eng. News, March 5, 1908) will be continued on a new plan and extended to cover the whole city. The first survey covered only a few wards of the city and was designed primarily to determine the economic effect of the fever on individuals and families. Future work, as we understand it, will deal with existing rather than past cases, and will include house-to-house and laboratory investigations. Like the previous studies, those to come will be prosecuted with funds provided by the Sage Foundation, of New York, but the new investigations will be in cooperation with Dr. J. F. Edwards, Superintendent of the Bureau of Health, and under the direction of a commission of five members to be appointed by Mr. Geo. W. Guthrie, Mayor of Pittsburg. This commission will appoint an executive officer and staff. It is said that the laboratories of the bureaus of health and water will be utilized by the survey. An advisory committee of 15 is also proposed. Particular attention will be given to other causes of typhoid than the water supply.

THE LUCIN CUTOFF of the Southern Pacific Ry. across the middle of Great Salt Lake is to be supplemented by a concrete breakwater for protection from wash, according to newspaper reports.

THE PURCHASE OF THE DRAINAGE AREA of the Pequannock River above the Macopin intake of the water supply of Newark, N. J., has been recommended by Mr. Jacob Haussling, Mayor, in a special message to the council. The city already owns 15 sq. mi. of the drainage area, of a total of 46. The authority to issue a million or more of bonds for protecting its water supply was granted the city by the last legislature. If the remainder of the drainage area was bought and cleared of habitations the small, but growing, villages of Newfoundland and Stockholm would be wiped out, besides a number of minor settlements.

THE PITTSBURG WATER FILTRATION PLANT is being put into operation as fast as the several beds are completed. On May 1, 1908, 23 beds were in use, the first having been started on Dec. 18, 1907. The average number of bacteria in the filtered water for the week ending April 25, regardless of the length of service, ranged from 24 to 200 for the 23 beds. B. coli have been found but 16 times since March 1, and never more than 2 per c.c. in one sample. In the river water coli are always present in numbers ranging from 5 to 30, and in the settled water in numbers varying from 3 to 6. Mr. Morris Knowles, M. Am. Soc. C. E., is Chief Engineer of the Bureau of Filtration, and the operation of the filters is in the direct charge of Mr. Chester F. Drake, Assistant Superintendent of Filtration. Prior to his appointment, about two months ago, Mr. Drake had been in charge of a number of small private water-works near Pittsburg, and before that he was engaged in construction work at Philadelphia.

MUNICIPAL OWNERSHIP OF WATER-WORKS by San Francisco, Cal., has been made easier by assurances from Washington that the city will be allowed to store water in Lake Eleanor and the Hetch-Hetchy basin. The permit will extend to flood waters only.

THE NEW WATER SUPPLY OF LOS ANGELES will be benefited by an extension of the Sierra Forest Reserve to include the Owens River valley. This extension was made by order of President Roosevelt, in April, 1908.

PERSONALS.

Mr. Paul V. Hyland, architect, has opened an office at 1001 Heyworth Building, Chicago, Ill.

Col. Henry M. Adams, Corps of Engineers, U. S. A., was retired from active service May 8, having reached the age limit.

Mr. R. A. Bainbridge has been appointed Division Engineer in Charge of Maintenance and Construction on the Esquimalt & Nanaimo Ry., with headquarters at Victoria, B. C.

Mr. W. C. Whittaker, of Birmingham, near Denver, Colo., has taken the place of Mr. C. A. Deweese, resigned, as master mechanic of the Denver & Rio Grande Ry., at Helper.

Mr. G. L. Wall, M. Am. Soc. M. E., has been retained by the Committee on Per Diem of the American Railway Association to compile the data upon which their report will be based.

Mr. Herbert C. Burchell, C. E., Manager of the North Sydney Cement Co., of Halifax, N. S., has been offered the appointment of Director of Works for Jamaica, by the British Colonial Office.

Mr. J. H. H. Muirhead, Civil Engineer, has resigned from the inspection force of the Isthmian Canal Commission. He will open an office in Panama City as resident representative for various contractors.

Mr. Everett E. Stone, M. Am. Soc. C. E., has succeeded Mr. Walter Shepard as Chief Engineer of the Boston and Albany R. R., with headquarters in Boston. Mr. Shepard has been appointed Consulting Engineer.

Mr. H. R. Fothergill has resigned as Superintendent of the Greenville, S. C., plants of the American Pipe Manufacturing Co., of Philadelphia. He will assume the duties of Engineer and Manager of the Scholl Engineering Co., of Youngstown, Ohio.

Mr. Daniel E. McComb, M. Am. Soc. C. E., has resigned as Superintendent of the Sewer Department of the District of Columbia, which position he has held for 21 years, to take charge of the Paving and Sewer Department of Havana, Cuba, as Chief Engineer.

Mr. C. H. Stotts has resigned his position as Manager of the Paint Department of the Joseph Dixon Crucible Company, which he has held for several years, to engage in business on his own account. His headquarters will be at the Engineers' Club, New York City, for the present.

Mr. H. G. Perring, Assoc. M. Am. Soc. C. E., Secretary of the Engineers' Club of Philadelphia, and formerly engineer with the Keystone Fireproofing Co., has been appointed District Manager at Philadelphia by the General Fireproofing Co., of Youngstown, Ohio, with offices in the Drexel Building.

Mr. Theodore Starrett and Mr. Edward A. Carpenter, former executive officers of the Thompson-Starrett Co., of New York, announce that they have formed a partnership as "Managers of Construction and Consulting Engineers" under the firm name of Theodore Starrett & Co., 103 Park Ave., New York City.

Mr. Wm. Renshaw has resigned his position as Superintendent of Machinery of the Illinois Central Ry., after more than 40 years' service with that road. He is succeeded by Mr. J. G. Neuffer, Assistant Superintendent of Machinery, who was formerly Superintendent of Motive Power of the Baltimore & Ohio Ry.

Mr. Ernest McCullough has succeeded Mr. A. W. Rush as Consulting and Sales Engineer for the Northwestern Expanded Metal Co., Chicago, Ill. Mr. E. H. Jones, formerly secretary and treasurer of the same company, has resigned. Mr. Howard N. Foote is now General Manager and Mr. W. G. Bartlett is Secretary.

Obituary.

George Kent Radford, M. Inst. C. E., died March 31 at his late residence in Berkeley, Cal., at the age of 81 years. After preliminary engineering experience in England, he acted from 1853 to 1858 as Assistant Engineer to Mr. A. M. Ross on the Grand Trunk Railway, Victoria Bridge and Toronto Water-Works. From 1858 to 1867 he, in conjunction with Sir John Fowler, laid upwards of two hundred miles of railways, the Sewerage water-works and the Millwall docks. He was consulting engineer of railways in Indiana from 1867 to 1878, in conjunction with Mr. Vaux, of Olmstead, Vaux & Co., of New York City, he designed and erected the Trinity Cemetery Suspension Bridge at Hartford, Conn., and the iron work of the Museum of Art and the Museum of Natural History of New York City. Mr. Radford was the brother of Wm. Radford, C. E., brother of Wm. Radford, Jr., C. E., and of Edward Radford, R. A. He leaves a son also in the engineering profession, Mr. Wm. Helsham Radford, Assoc. Am. Inst. M. E.

ENGINEERING SOCIETIES.

COMING MEETINGS.

AMERICAN WATER-WORKS ASSOCIATION.
May 11-16. Annual meeting at Washington, D. C. Secy., John M. Diven, 14 George St., Charleston, S. C.

NATIONAL ELECTRIC LIGHT ASSOCIATION.
May 19-22. Annual convention at Chicago. Secy., W. W. Freeman, 29 West 39th St., New York City.

NATIONAL FIRE PROTECTION ASSOCIATION.
May 26-28. Annual meeting at Chicago. Secy., W. H. Merrill, Jr., 382 Ohio St., Chicago.

AMERICAN FOUNDRYMEN'S ASSOCIATION.
June 9-11. Annual convention at Toronto, Ont. Secy., Richard Moldenke, Watchung, N. J.

MASTER CAR BUILDERS' ASSOCIATION.
June 17-19. Annual convention at Atlantic City, N. J. Secy., Jos. W. Taylor, 390 Old Colony Bldg., Chicago.

AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION.
June 22-24. Annual convention at Atlantic City, N. J. Secy., Jos. W. Taylor, 390 Old Colony Bldg., Chicago.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
June 23-26. Annual convention at Denver, Colo. Secy., C. W. Hunt, 220 West 57th St., New York City.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.
June 23-26. Annual convention at Detroit, Mich. Secy., C. W. Rice, 29 West 39th St., New York City.

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION.
June 23-26. Annual meeting at Detroit, Mich. (In connection with convention of American Society of Mechanical Engineers.) Secy., A. L. Williston, Pratt Institute, Brooklyn, N. Y.

AMERICAN SOCIETY FOR TESTING MATERIALS.
June 23-27. Annual meeting at Atlantic City, N. J. Secy., Edgar Marburg, University of Pennsylvania, Philadelphia.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.
June 29-July 2. Annual convention at Atlantic City, N. J. Secy., Ralph W. Pope, 33 West 39th St., N. Y.

SOUTHERN SUPPLY AND MACHINERY DEALERS' ASSOCIATION.—This association holds a convention May 13, 14 and 15 at the Jefferson Hotel, Richmond, Va.

INTERNATIONAL HIGHWAY CONGRESS.—This congress, whose objects were fully noted in a previous issue of Engineering News, will be held Oct. 11 to 17, at Paris, France. The Secretary General is Mr. Heude of the Ministry of Public Works, 244 Boulevard St. Germain, Paris.

DETROIT ENGINEERING SOCIETY.—On April 17 the society in annual meeting elected officers as follows: Pres., Francis C. Shenehon, U. S. Lake Survey; First Vice-Pres., Byron E. Parks, C. C. Wormer Machine Co.; Second Vice-Pres., Chas. G. Herbert, M. Am. Soc. M. E., Engr., Solvay Process Co.; Sec.-Treas., Bamlet Kent, U. S. Engineer's Office.

CIVIL ENGINEERS' CLUB OF CLEVELAND, OHIO.—On April 18 the Electric Club of Cleveland was amalgamated with the Civil Engineers' Club of that city. The officers elected by the latter for 1908 are Willard Beahan, M. Am. Soc. C. E., President; Robert Hoffman, M. Am. Soc. C. E, Vice-President; Joseph C. Beardsley, Secretary; John H. Fox, M. Am. Soc. M. E., Treasurer.

AMERICAN RAILWAY ASSOCIATION.—At the spring session, held April 22, and briefly noted in our last issue, the association adopted a resolution requesting the Master Car Builders' Association to investigate the subject of a uniform nomenclature for different classes of cars and to return the result for final action. A sub-committee of the Executive Committee presented a report on the proposed connection of the various voluntary associations of railroad officials with the American Railway Association. A Code of Air Brake and Train Air Signal Rules was adopted and made part of the Standard Code of the association. The Committee on Standard Rail and Wheel Sections in its very complete report presented two types, with specifications for Open Hearth and Bessemer steel rails, for proper method of track-gage measurement, and for distance between main rail and guard rail, which were adopted by the association as recommended practice. Acting on the report of the Committee on Standard Location for Third Rail Working Conductors, resolutions were also adopted for the standardization of such equipment.

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